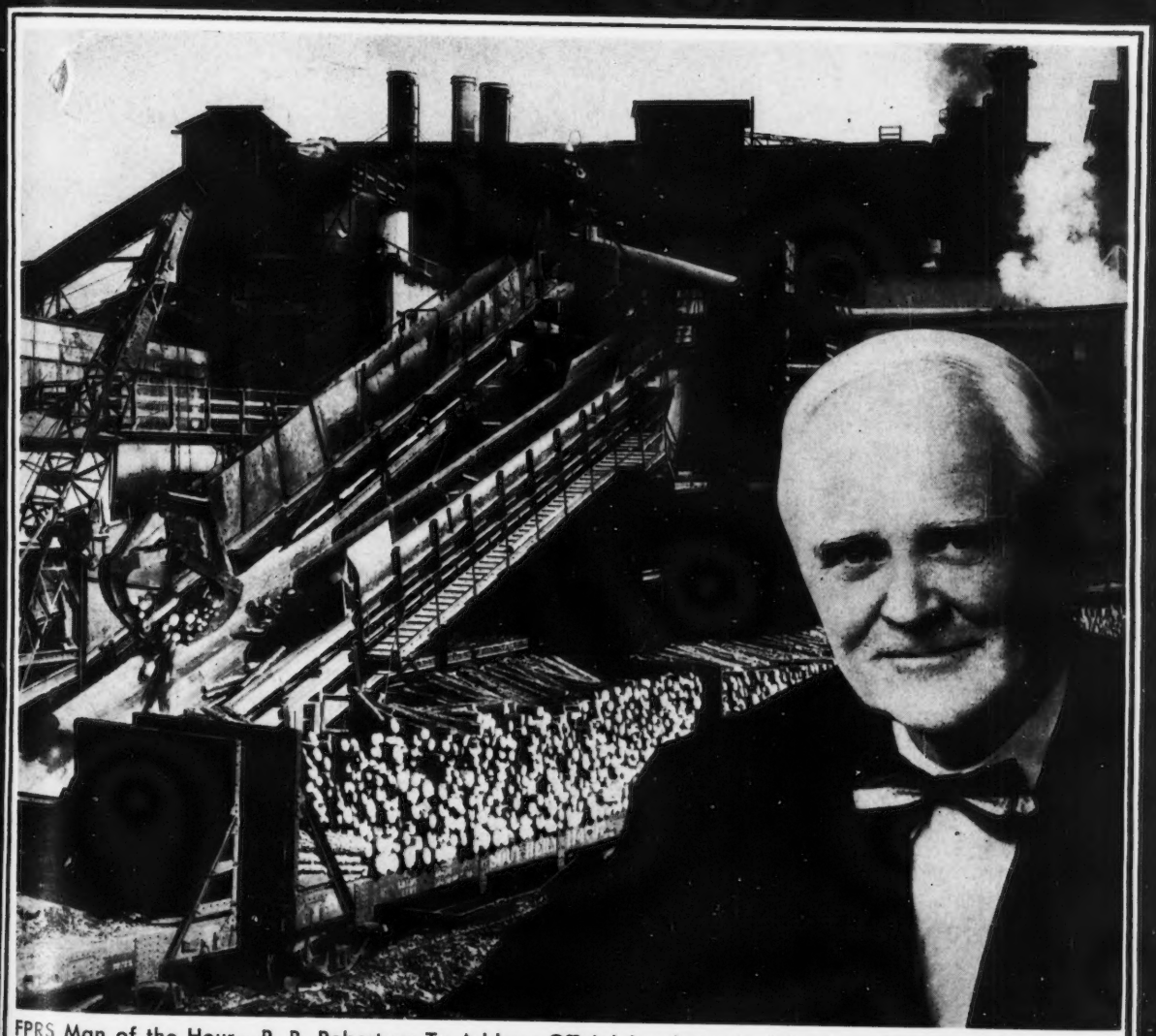
HOW TO INSTALL SAWMILL MACHINERY—p. 137

Forest Products Journal



FPRS Man of the Hour—R. B. Robertson To Address Official Luncheon in Asheville—See pages 14–A, 15–A

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New particle board

BINDER RESIN

...offers 7 big advantages!

MELURAC® RESIN 304

1. *Lower cure temperature or faster cure cycles:* With MELURAC Resin 304 you can use up to 15°F – 25°F lower cure temperature or 10-15% shorter cure cycle at the same temperature.

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3. *High strength:* MELURAC 304 gives you maximum flexural strength.

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5. *Lighter color:* MELURAC 304 imparts no color to the board. This new freedom from color can be a very important advantage for applications whose outer surface is the particle board itself.

6. *Easy handling:* MELURAC 304 is a melamine-urea-formaldehyde resin . . . a white, finely divided, free-flowing powder, dispersible in water if necessary.

7. *Economy:* With MELURAC 304 you can make *better* hardboard at a cost competitive with ordinary resins.

USES: Wall panels, table tops, furniture cores, veneer bases, and high-density board for flooring.

To make fuller and better use of wood, with less waste of this basic natural resource, use MELURAC 304. Write today for complete information, samples or the assistance of a Cyanamid Technical Service Representative.

CHEMICAL PROGRESS WEEK-APRIL 23-28

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IMPORTANT FPRS DATES

Spring 1956: Mid-South Section Plant Tour to Kirby Co., Lufkin, Texas

April 26–27: Great Lakes Section Meeting, Manistee, Mich.

May 2–3: Midwest Section Meeting, Dubuque, Iowa

May 7–8: Pacific Northwest Section Meeting, Eugene, Ore.

May 17–18: Ohio Valley Section Meeting, Jasper, Ind.

June 4–7: Tenth National Meeting, Asheville, N. C.

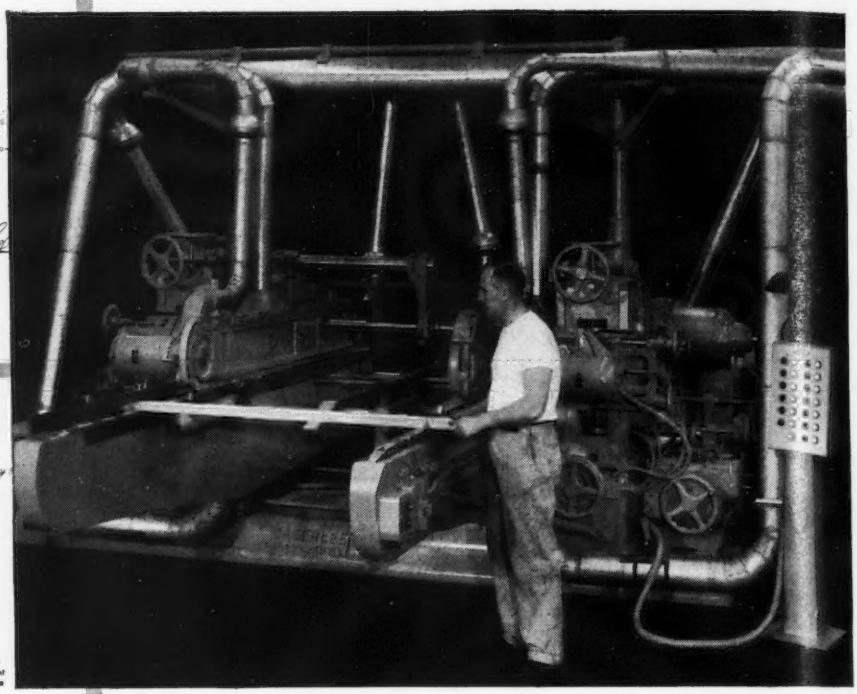
Fall 1956: Mid-South Section Annual Meeting, Laurel, Miss.

Dec. 7–8: Florida–Georgia–Alabama Section Annual Meeting, Athens, Ga.

What owners say about

SERVICE AND DURABILITY

of the Greenlee No. 545 Double-End Tenoner



"Constant and sincere attention you give your customers in service is as valuable as the product itself."

H. L. HUBBELL, H. L. HUBBELL MFG. CO.

"The No. 545 Double-End Tenoner, purchased in 1931, has given us almost astonishing service and performance. Aside from general maintenance we have not spent one cent on the machine."

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"The first No. 545 has been running continuously every day since January, 1950, We have had absolutely no repairs."

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Comments like these from furniture and woodworking industry leaders show what you, too, can expect in the way of durability and service when you put a GREENLEE No. 545 Double-End Tenoner into your production line. Often called "a woodworking plant in itself" . . . because it can perform numerous different operations swiftly and accurately . . . the No. 545 today is found in practically all of the nation's leading woodworking plants. Matching its unusual versatility is its long record of trouble-free precision operation. When you put it on the job, *it stays on the job* to continuously give you the kind of production increases and efficiencies you need to meet today's competitive conditions.

MACHINERY & TOOLS
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The Famous Hubbell File Chests
OLDE AND FINE FURNITURE

H. L. HUBBELL MANUFACTURING COMPANY
ZEELAND :: MICHIGAN

October 2o, 1955

Greenlee Bros & Company
Rockford
Illinois

Attention: Mr. J. A. Lenquist, Sales Manager

Gentlemen:

We appreciate your letter and your enclosure with the desire to use this in your advertising literature. This is quite alright with us. . .

I would like to say also that your machine is giving the continued good performance it has from the start. One of the finest attributes to your organization is the constant and sincere attention you give your customers in service which is as valuable as the product itself.

We are,

Very truly yours,
H. L. HUBBELL MFG. CO.
H. L. Hubbell

HLHkpm

KINDEL
Grand Rapids

Kindel Furniture Company, Grand Rapids 2, Michigan, Cherry

October 26, 1955

Greenlee Brothers & Company
Rockford
Illinois

Attention: Mr. J. A. Lenquist

Dear Mr. Lenquist:

We very much appreciated your recent visit. Our conversation, brought us to realize that the #545 Double End Tenoner, which we purchased from you in 1931, has given us almost astonishing service and performance.

Actually, in the time this machine has been in use, the rubber hold-downs have been replaced three times. Aside from our general maintenance, which we try to maintain to the highest degree, we have not spent one cent on the machine. As a matter of fact, the chain and tracks are the original, and the machine is doing an extremely fine job of cutting square and maintaining the original accuracy.

This machine is working every day, and has been operated continuously by the same man since its installation . . . and he joins me in enthusiasm for the machine.

The ownership of this machine has been a pride and satisfaction, and we felt that we should tell you about it.

With kindest personal regards,

Yours very truly,
Vice President

CM Kindelbd

The Best Windows a Wood Window R·O·W The Best Wood Windows are R·O·W

R·O·W WINDOW COMPANY
MIDLAND AVENUE & ROCK ISLAND R. R.
(POST OFFICE)

December 16, 1955.

Mr. J. A. Lenquist, Sales Manager,
Greenlee Bros. & Company,
Rockford, Illinois.

Dear Mr. Lenquist:

Acquisition in March, 1955, of another #545 Tenor enabled us to increase our production approximately 23% this year. Only a small fraction of this gain would have been possible without this purchase, and our labor cost would have been higher. As a result, our direct labor cost to sales was slightly lower despite an increase of 12¢ per hour.

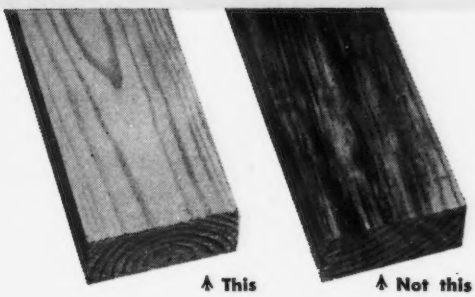
We like Greenlee Bros.' Tenoners because they product high quality products year after year without costly repairs. The first #545 has been running continuously every day since January, 1950. We have had absolutely no repairs, but did replace the feed track with your new type last year altho we know this purchase was premature, and made only because we just like to have the most modern equipment available.

With such experience in our own plant, you can't blame us for being so enthusiastic about Greenlee products. They do deliver exactly as advertised.

Yours very truly,
R. O. W. WINDOW COMPANY,
A. E. Beirnes, President.

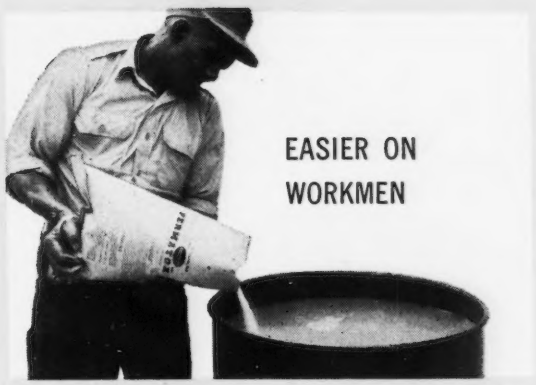
AEB/da

Get bright, clean, higher-value lumber with improved PERMATOX 10-S



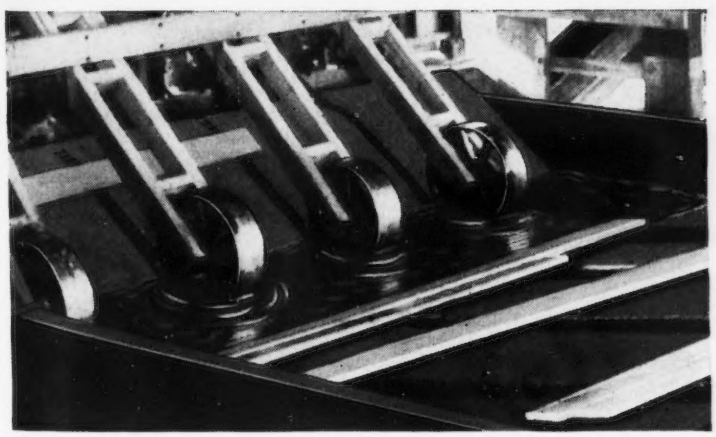
PREVENTS SAP STAIN AND MOLD

Lumber treated with Permatox 10-S is bright and clean. For a few cents per thousand you can prevent costly degrade because of sap stain and mold . . . thus insuring customer satisfaction.



EASIER ON WORKMEN

No irritating dust problem with improved Permatox 10-S. The addition of a new ingredient makes it practically dust-free, easier for workers to handle and mix than ever before.



Mechanical dipping vat, as shown here, is the usual method of applying Permatox 10-S. Lumber also can be sprayed or dipped in bulk. Hand dipping is often used at small mills. Consult Chapman for details.

Permatox 10-S

- Prevents stain, mold and decay in lumber during air seasoning.
- Costs only a few cents per thousand.
- Can be applied by dipping or spraying . . . equipment needed is inexpensive and easy to build.
- Can be mixed with Chapman Ambrocide to protect lumber from ambrosia beetles and other insects.

CHAPMAN CHEMICAL COMPANY
Memphis 1, Tennessee • Portland 9, Oregon

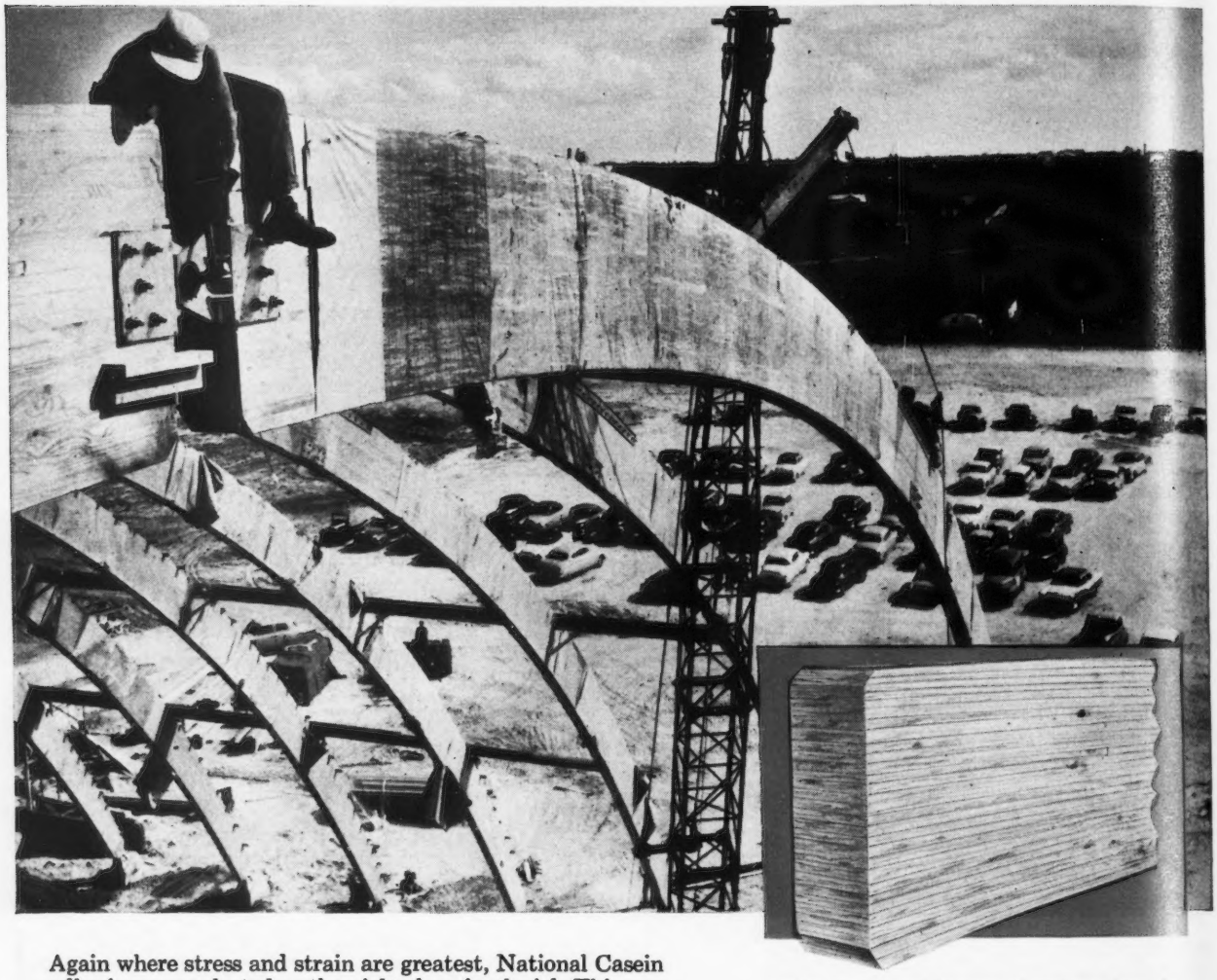
Write for helpful Bulletin 51-S on stain, mold and insect control.

CHAPMAN®

PERMATOX 10-S

Prevents both sap stain and mold, in freshly cut hardwoods and softwoods

'Unit Structures'* fabricates world's largest wood arches with National Casein glues!



Again where stress and strain are greatest, National Casein adhesives are selected as the *right glues for the job.* This time, for the laminated wood arches used in the new Jai Alai Fronton at West Palm Beach—a building that breaks structural records and establishes construction precedents.

Jai Alai requires a large indoor playing area unencumbered by posts. Such an area, with a seating capacity of 3,500 was provided by use of the largest glued laminated wood arches ever manufactured.

Bonds of National Casein glue for the laminated elements of these arches test stronger than the wood.

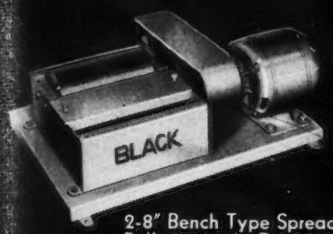
You, too, may have a tough adhesive problem. We sincerely believe that we can help you. Write the National Casein office nearest you. No obligation.

Arches are unusual because of variance from the usually constant cross section. At the crown, the cross section measures 20 inches, at the base 25 inches, and at the point of maximum stress, 46 inches. Hinged to buttresses, the arches soar to a height of 80 feet at the crown — equivalent to eight stories in a building. Each arch has a clear span of 247 feet, a lineal arc measurement of 340 feet. The clear span is nearly 50 feet greater than that of any wood arches previously manufactured. Standard sizes of two inch thick Southern Pine lumber are glued and shaped in specially engineered presses.

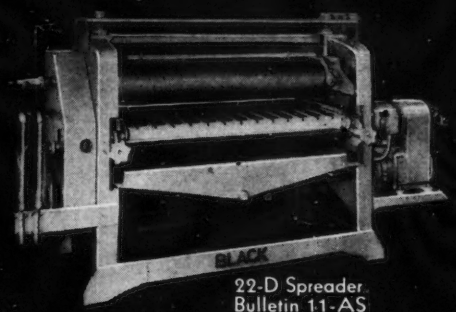
National Casein

*Arches were shipped by train from the Magnolia, Arkansas plant of Unit Structures, Inc.

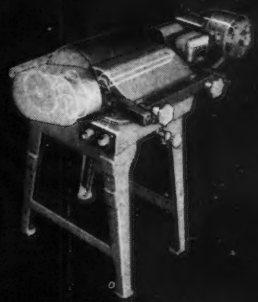
601 W. 80th St., Chicago 20, Broad & Fulton Sts., Riverton, N. J.

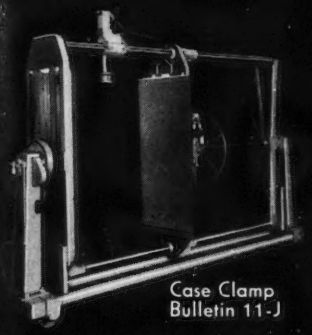


2-8″ Bench Type Spreader
Bulletin 11-A, Part 1



22-D Spreader
Bulletin 11-AS


No. 567 Spreader
Bulletin 11-A, Part 2


Case Clamp
Bulletin 11-J

First in Production, Quality, Economy

BLACK BROTHERS EQUIPMENT

. . . for gluing, clamping, laminating

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The most complete line in the world—for hot or cold glues. Single or double spreaders from 8″ through 122″ roll widths.

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Cold Glue Mixers—10 to 400 gal.; Portable Motor Driven Cold Glue Mixers—2 to 15 gal. Glue Heaters for steam, electric or gas heat—2½ to 125 gal.; Portable Pot Glue Heaters.

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A wide line of high-production presses: Rotary-type; Air-Hose; Electric, Hydraulic and Hand Power Laminating Presses. Efficient, accurate, economical.

PRODUCTION CLAMPS

A production clamp for every need: Case Clamps—hand-powered or pneumatic, revolving or stationary; Clamp Carriers; Sash, Frame and Door Clamps.

THE BLACK BROTHERS CO., INC.

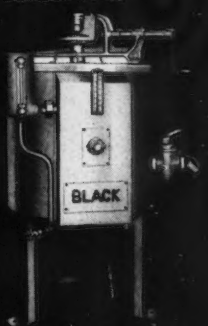
MENDOTA 8, ILLINOIS

Cold Glue Mixer
Bulletin 11-I

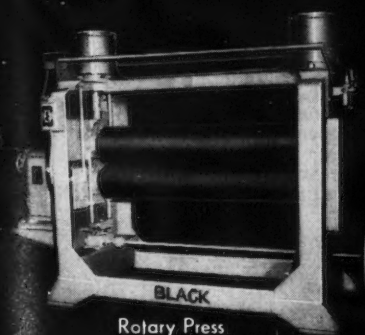
Clamp Carrier
Bulletin 11-K

Portable Glue Mixer
Bulletin 11-IS

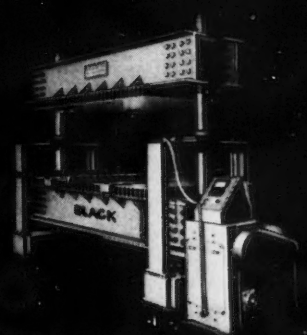
Sash, Frame and Door Clamp
Bulletin 11-M



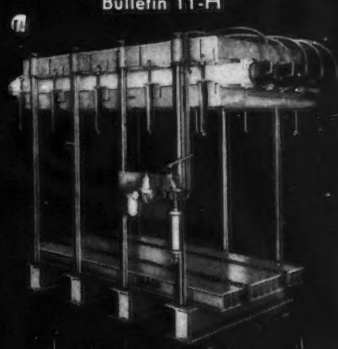
No. 700 Series Glue Heater
Bulletin 11-H

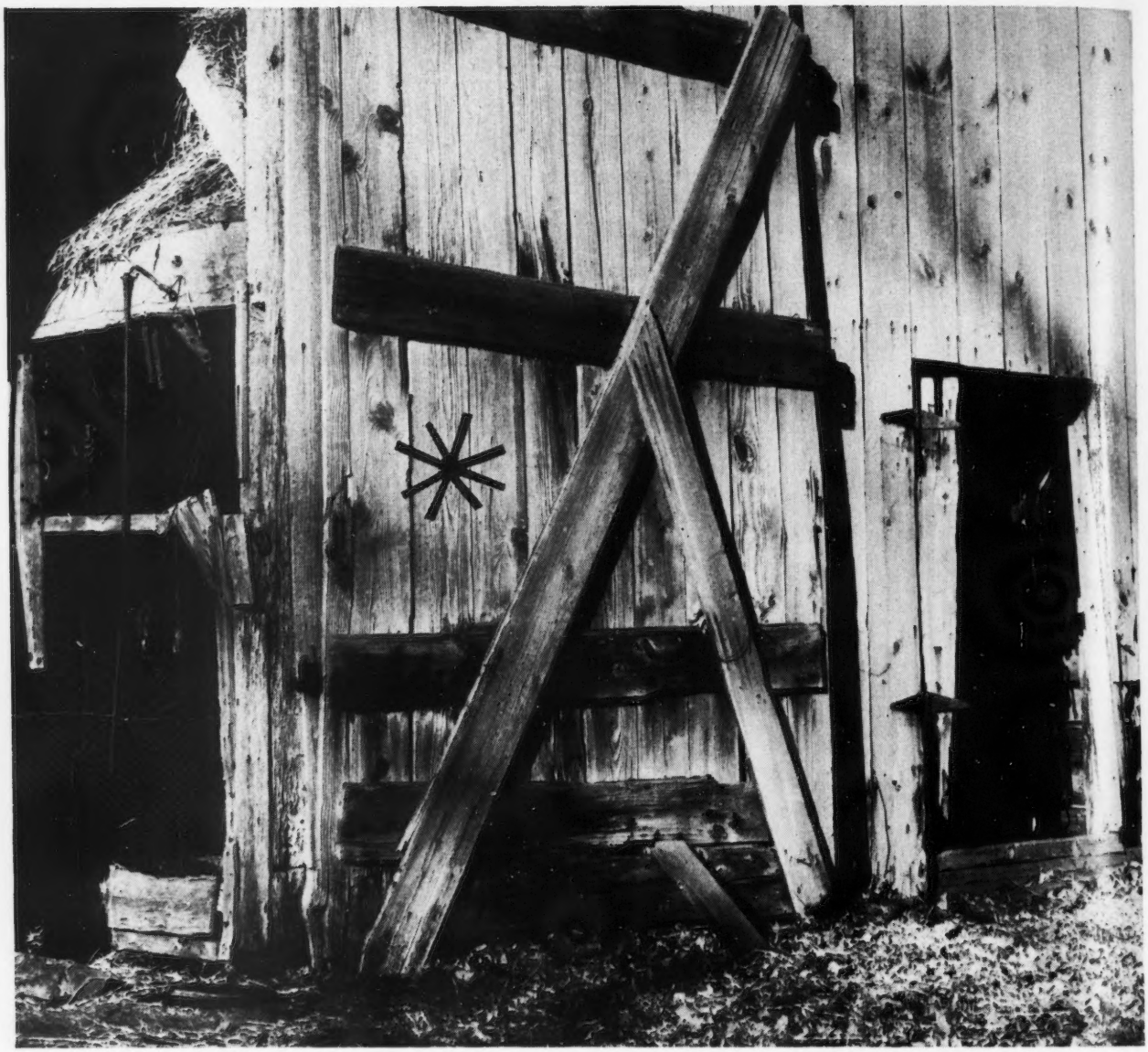


Rotary Press
Bulletin 11-C



Motorized Laminating Press
Bulletin 11-E


Air Hose Laminating Press
Bulletin 11-D



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Wood protected by RCI Penta solutions is clean, easy to handle . . . lasts up to 4 times as long as untreated lumber.

Penta treatment is proven. For years it has helped keep down expenses for light and power companies, railroads, highway departments by deferring wood replacement . . . cutting wood maintenance costs.

If you're currently engaged in, or are considering, the manufacture of wood preservative solutions, fungicides, bactericides, algicides, or herbicides . . . or the penta treating of lumber, we invite you to consider Reichhold as a source of supply for pentachlorophenol . . . now being produced by RCI's Pacific Northwest Division in Seattle.

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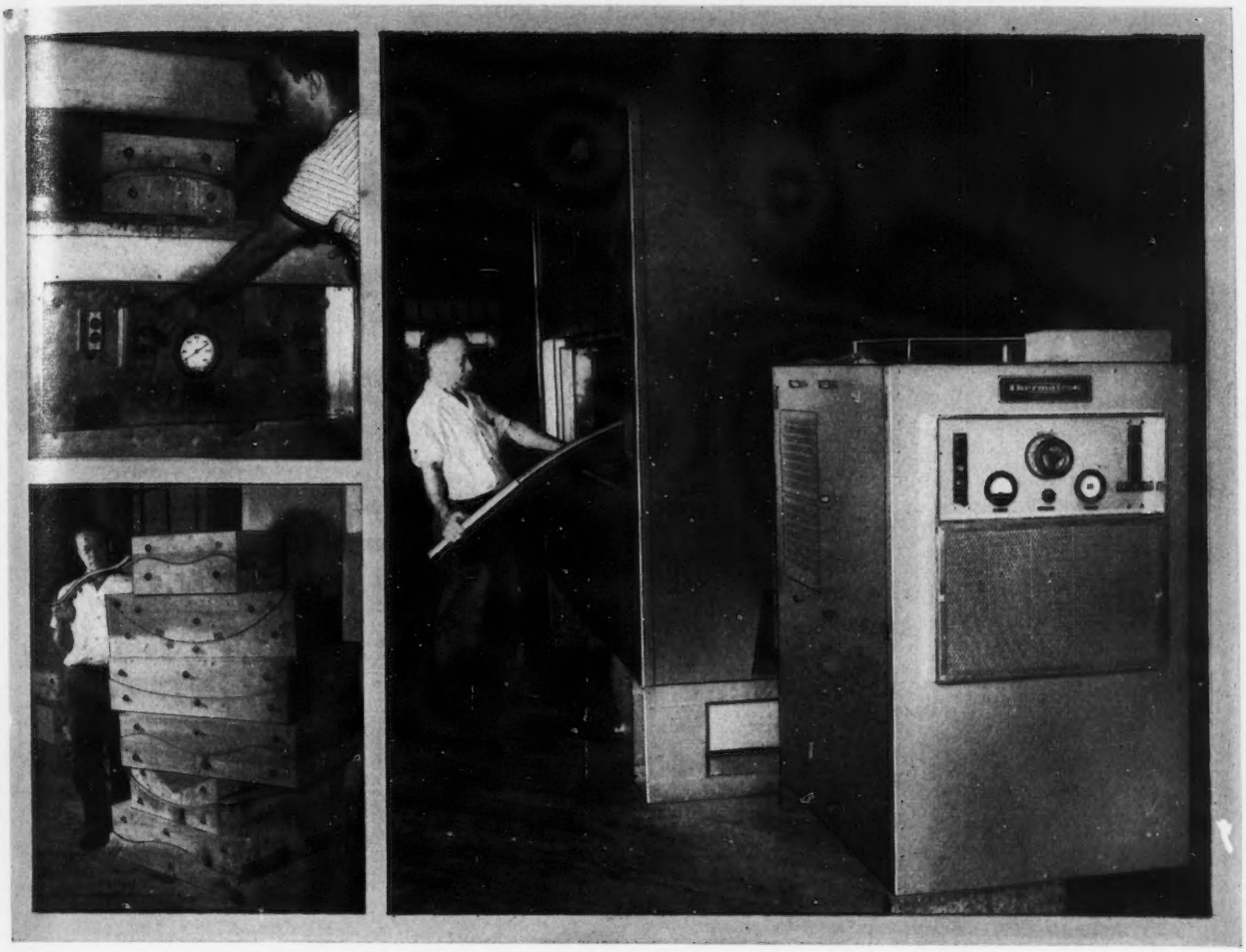

Now Pennsylvania Furniture Co. bends and laminates fine veneer serpentine fronts in a fraction of the former time with THERMATRON

The old method of gluing in a cold press used to require almost three hours, but the THERMATRON high frequency installation in Pennsylvania Furniture Co.'s York, Pa. plant has created a revolution! Using the 15 KW output THERMATRON generator and 225 ton plywood forming press illustrated, as many as several layups of six to ten pieces of veneer are precision bent and laminated at once over their inexpensive hardwood moulds . . . And the time cycle is no more than 2¾ *minutes*. Other than loading, it's a push-button operation throughout, with no special skills required.

We'd like to survey *your* present operation. We can prove that THERMATRON high frequency equipment will do a superior job while it slashes away at costs. Frees large drying areas for more profitable purposes, too. Write or phone us now without obligation — And ask for our latest bulletin #FP-10.

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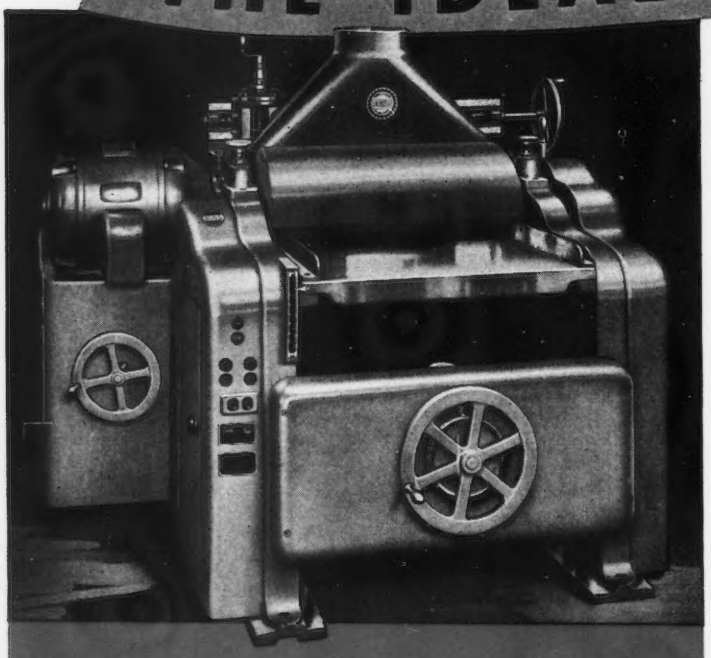
BUSS No. 44

THE IDEAL PLANER



BUSS No. 44 — 4 roll, single surface planer. Capacities: 26" through 50". Feeds up to 105' P.M.

for ROUGH MILL CONVEYORIZED SET-UPS!

Already MORE THAN 100 LEADING MANUFACTURERS ARE USING IT IN THIS TYPE OF OPERATION

If you are contemplating a rough mill conveyorized hook-up, by all means investigate the reasons why the BUSS No. 44 planer has been chosen for the vast majority of such existing operations. Here are some of them:

1. The distance between frames is sufficient, in both 30" and 36" models, to match up perfectly with Facer Feeders of similar capacity. You pay for no unused capacity in width of machine.
2. The BUSS ONE-SHOT lubrication system insures perfect lubrication at all points — a particularly advantageous feature in a conveyorized set-up.
3. Lower rolls and pressure bar are instantly adjustable at the flick of a lever — providing great time-saving and accuracy.
4. Drop-forged steel infeed roll sections are unbreakable.
5. Cutterhead and feed motors are of extra heavy duty capacity.
6. Positive protection is provided against lumber jamming or blocking of feed mechanism.

These and many other structural superiorities make the BUSS No. 44 by far the best machine for conveyorized set-ups. Write for descriptive bulletin.

THE BUSS LINE **contains the ideal planer for every production set-up — single surface planers in various capacities, a cabinet double surface planer and the No. 55 double roughing planer. Write for bulletins.**

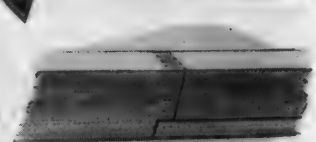
PRECISION BUSS PLANERS

PLANER SPECIALISTS EXCLUSIVELY

292 EIGHTH STREET, HOLLAND, MICHIGAN

BUSS
SINCE 1862
MACHINE WORKS

For better bonds . . . for finer service . . .
call MONSANTO



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Melamine . . . comparable to the phenolics and resorcinols in durability. Used in wood gluing applications where a colorless glue line is essential.

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Soybean and Soybean Blend...unexcelled for low-cost production of interior grade water-resistant plywood by cold press and No-Clamp methods.

Urea . . . a comprehensive line of powder and liquid resins for plywood manufacture. Also for edge gluing of lumber in clamps or by high frequency, and for tapeless splicing of veneers.

For full information on Monsanto's complete line of adhesives, write to Monsanto Chemical Company, Plastics Division, Room 464, Springfield 2, Mass.

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The Perkins Trade Mark is your guarantee of quality and reliability when you purchase glues. Since 1899, customer-confidence in Perkins has grown steadily—a deserved tribute to superior products backed by competent service and rigid ethical standards. When you use a Perkins Glue in your operations, you'll agree with other leading woodworkers—*that Perkins serves you best!*

GLUING PROBLEMS?

Dispose of them by calling upon the skilled assistance of the Perkins Technical Service Department. Specialists in gluing methods will study your particular operations and offer suggestions where pertinent. There is no cost or obligation involved in your use of this unbiased advice.

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RESIN—Hot Press and Cold Press • Liquid or Powder Type
CASEIN—A broad line to meet your specific requirement
VEGETABLE—As originated and perfected by Perkins Glue Co.
ANIMAL—Ready-to-use Liquid • Heat-then-use Gel

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VENEER AND CORE REPAIR COMPOUNDS • VENEER SIZE
GLUE ROOM SPECIALTIES • MIXERS • SPREADERS • BRUSHES

RESIN
CASEIN

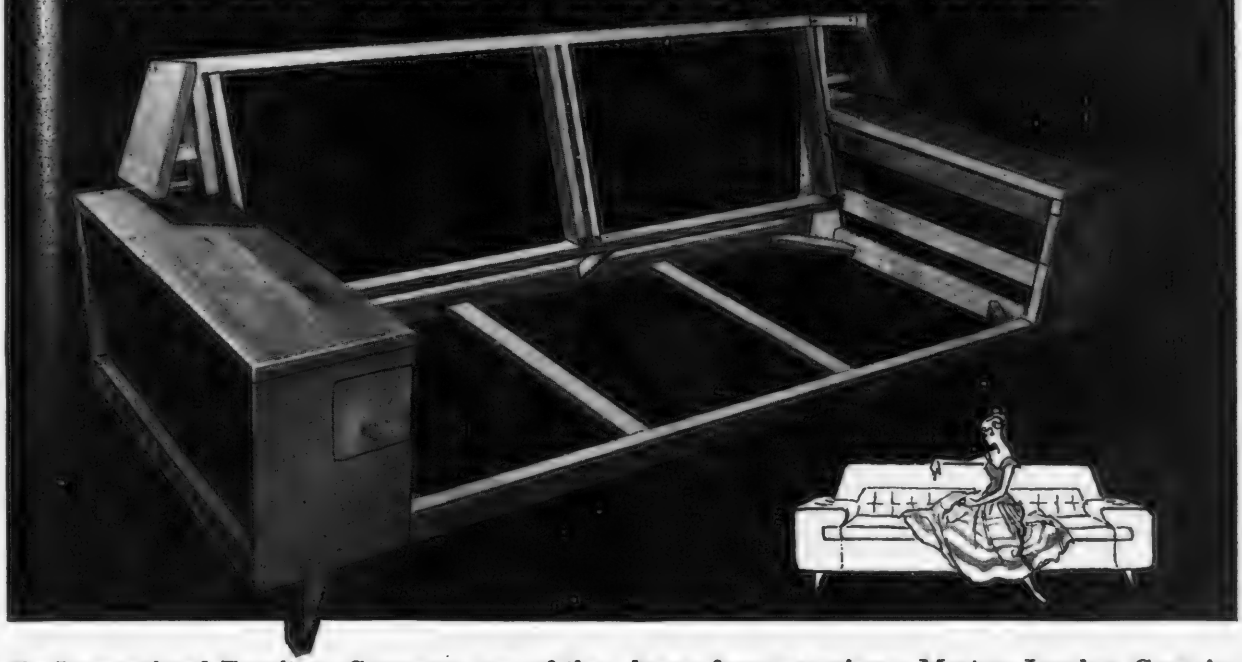
PERKINS

VEGETABLE
GLUES

ESTABLISHED 1899

LANSDALE, PA. KITCHENER, ONT.

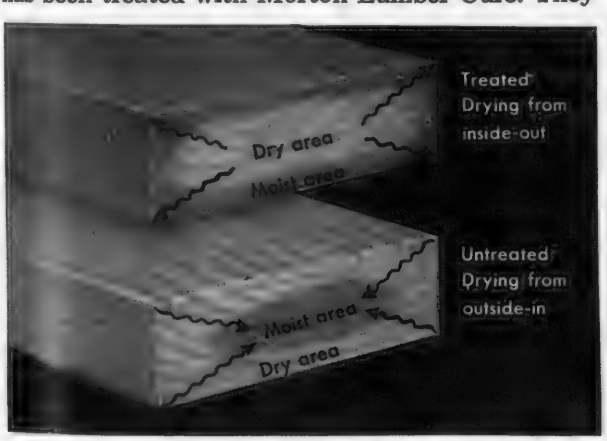
Leading manufacturers insist on Morton Lumber Cure treated lumber



The International Furniture Company, one of the leading furniture manufacturing companies, and makers of the sofa frame shown above, has been using Morton Lumber Cure treated lumber since 1948. International has found Morton Lumber Cure greatly increases yield; reduces end checking, surface checking, and tear-outs.

Hundreds of fabricators now insist on lumber that has been treated with Morton Lumber Cure. They know from experience Morton Lumber Cure increases utilization of rough cut lumber. Lumber also can be dried faster, kiln time and expense are reduced, with a more rapid turnover of inventory and capital.

What's more, Morton Lumber Cure is compatible with stain-preventing agents . . . will not affect gluability . . . machinability . . . color or finish. Morton Lumber Cure is non-toxic and non-corrosive.



How Morton Lumber Cure Works • Morton Lumber Cure reverses the normal drying action. Untreated lumber dries from the outside in. Morton Lumber Cure dries lumber from the *inside out.* This controlled drying greatly reduces checks, honeycomb, warping, and other types of wasteful surface and interior degrade.

SEND FOR MORE INFORMATION TODAY!

Bay Chemical Company
DIVISION
Morton Salt Company

120 So. La Salle Street, Dept. FPJ-4, Chicago 3, Illinois

Please tell me how Morton Lumber Cure can help *me* increase my sales and satisfy customers.

Name_____

Title_____

Company_____

Address_____

City_____ State_____

Announcing —

The New, Revised

HOUGH'S ENCYCLOPAEDIA OF AMERICAN WOODS

. . . The Textbook of the Industry

FACT This long-out-of-print classic is now being published in Fifteen handsome volumes. Volumes I and II will be shipped this year to our subscribers, with further volumes in the set to be shipped in successive years as prepared.

FACT The entirely new text is written by Dr. Ellwood Scott Harrar, Professor of Wood Technology, School of Forestry, Duke University.

FACT Authentic wood sections, consisting of radial, tangential, and transverse slicings of the **actual wood**, are cut by CARDS OF WOOD, the exclusive owners of the Romeyn B. Hough process.

FACT Each volume of the set contains twenty-five different actual woods. Each specimen consists of three 2″ x 5″ sections, transverse (end grain), tangential (plain-sawed) and radial (quarter-sawed) mounted on a 6″ x 9″ Bristolboard. The accompanying text for each volume comprises an authoritative treatment of the technical properties and uses of each wood. Space is also devoted to a discussion of pertinent features leading to the identification of each species, its geographical distribution, and value for ornamental use.

FACT Volume I contains **actual** wood slicings and text covering twenty-five Coniferous Species; Volume II contains **actual** wood slicings and text covering twenty-five Hardwood Species. Each of the succeeding Volumes will also contain twenty-five different important and characteristic American timbers. A supplementary volume will be devoted to the Exotic Woods.

FACT HOUGH'S ENCYCLOPAEDIA OF AMERICAN WOODS is offered to subscribers only at the pre-publication price of $15.00 per volume Net—no discount. After publication the price will be $25.00 per volume in bookstores—and bookstore copies will not be available until sometime in 1957.

ROBERT SPELLER & SONS, PUBLISHERS
1201 West Chapel Hill Street
Durham, North Carolina

I enclose $30.00 for my copies of Volumes I and II of HOUGH'S ENCYCLOPAEDIA OF AMERICAN WOODS. Orders now being accepted will be shipped postpaid, as ready, in order of receipt of subscription.

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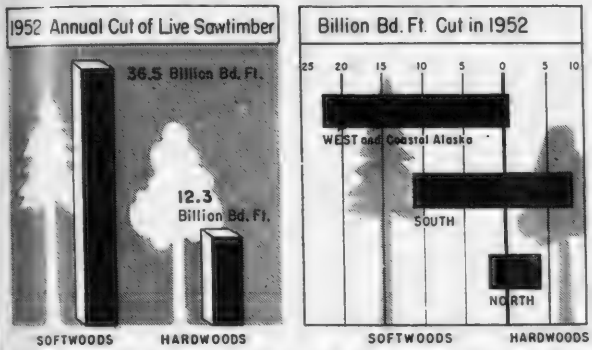
Street _____ State _____

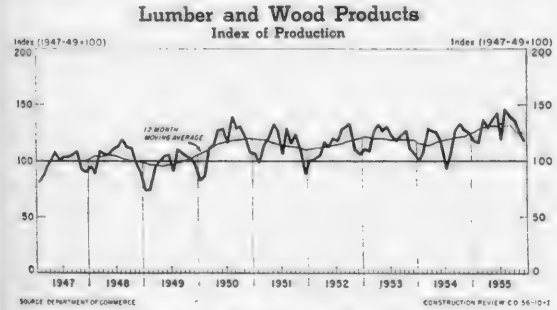
FPRS NEWS-DIGEST

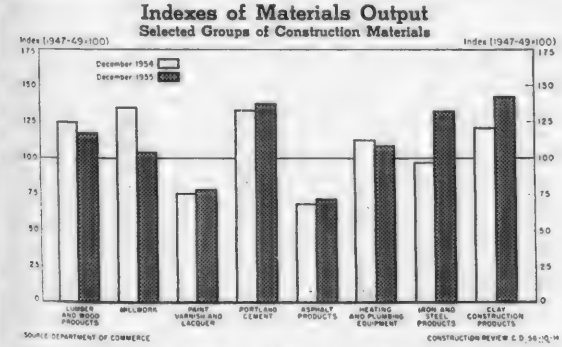
Volume VI APRIL, 1956 Number 4

GRAPHIC TRENDS



Softwoods provided three-fourths of 49 billion board feet of sawtimber cut from commercial forest land in 1952, according to preliminary drafts of Timber Resource Review, U. S. Forest Service. Douglas-fir, southern yellow pine, oak, ponderosa pine, and western hemlock accounted for 70 per cent of timber cut.





UTILIZATION-MINDED INDUSTRY in Oregon is pointed out by fact 200 sawmills and plywood plants have installed chippers. Pulp industry in state now uses 600,000 tons of wood residues annually, compared with only 1350 tons in 1944.

—50 Years of Forestry at Oregon State College

BUSINESS OUTLOOK

RECORD-BREAKING 39.105 billion board feet of lumber was produced in U. S. in '55, according to NLMA. Softwood output rose 8% over '54, hardwoods were up 1%. Lumber production continued to climb in January '56, with 2.933 billion board feet, 4% above same month last year, for highest first-month output since 1948.

—Timber Digest, April 1956

HIGH-LEVEL PACE of furniture industry started in January was continued in February, with shipments up 27% over same month in '55. Coupled with 26% increase in January, shipments for first two months were 26% ahead of '55, best year in the history of the industry.

—NAFM

BUSINESS MAINSTAYS in British Columbia are forest industries, according to estimate of Canada's economic prospects. In '55, forest industries produced $580 million or 40% of B.C.'s net value of production. Assuming a minimum population growth, in 1975 forest industries will produce $1.357 billion or 38% of province total.

—What's Happening in Forestry

IMPROVED UTILIZATION of wood will help increase Oregon's timber industry payrolls by 25% in next 10 years, predicts Governor Elmo Smith. He forecast an increase of 25,000 jobs in the industry which already brings $1 billion into the state and employs 100,000 persons. This increase will result from use of sawmill leftovers, estimated to be worth $22.5 million annually in a single county. Today 2 billion board feet of once-wasted wood is yielding returns to sawmills and plywood plants.

10 Plant Tours Planned During Annual Meeting

Ten leading forest products companies in western North and South Carolina are opening their doors to persons attending FPRS' Tenth National Meeting June 4–7 in Asheville, N. C. The tours will be conducted on Friday, June 8, following four days of technical sessions.

Meeting registrants may sign up for the trips beginning Monday, June 4, and continuing through Wednesday, June 6. Transportation will be provided to all plants.

An extrusion-type particle board plant will be visited at Broyhill Furniture Factories, Lenoir, N. C., manufacturers of bedroom furniture and chairs. A modern conveyor system is a feature at Drexel Furniture Co., Drexel, N. C., makers of dining room and bedroom furniture. A third furniture plant included on the tour is Morgan Manufacturing Co., Black Mountain, N. C., producers of completely fabricated furniture dimension stock, machined wood parts, and television cabinets.

For persons interested in pulp and paper products, visits will be made to Champion Paper and Fibre Co., Canton, N. C., which has a new 7-stage bleach plant, 242-inch Fourdrinier machine, and barking drum; and Ecusta Paper Corp., Pisgah Forest, N. C., one of the largest producers of cigarette papers in the world. The latter firm also produces cellophane, polyethylene, and fine thin specialty papers.

Included on the tour will be the hardwood dimension plant of Williams–Brownell, Inc., Asheville, featuring straight member laminating and paneling production. Five new prefabricated dry kilns will be viewed at Draper Corp., Swannanoa, N. C., makers of rough dogwood shuttle blocks and hickory picker sticks. A visit is planned to Taylor–Colquitt Co., Spartanburg, S. C., largest preservative treating plant in the East. The vapor drying process will be observed at this plant, which treats poles, piling, cross ties, fence posts, and lumber.

A flat press process particle board plant will be seen at Poinsett Lumber and Manufacturing Co., Pickens, S. C., division of Singer Sewing Machine Co. which makes sewing machine cabinets, tables, and portable carrying cases. Also visited at this firm will be the band mill and veneer mill. A visit will be made to American Enka Corp., Enka, N. C., producers of rayon and nylon and one of the largest single rayon units of its kind in the world.

Asheville Boasts Many Scenic Attractions

Persons attending FPRS' Tenth National Meeting June 4–7 in Asheville, N. C., will have ample opportunity to view many scenic attractions in this picturesque area. Many are planning to bring the whole family and make it a work and fun vacation.

Blue Ridge Parkway, which extends from Shenandoah National Park in Virginia to Great Smoky Mountains National Park west of Asheville, is a nearly 500-mile balcony from which to view some of America's finest scenery. Pastoral farmlands and rustic log cabins emphasize the rural atmosphere of the region, while upland meadows, sweeping mountain vistas, and densely forested valleys present a variety of fascinating views.

Blue Ridge Parkway extends through an area noted for its picturesque contrasts. An example of the varying landscape is in Doughton Park, with its bluegrass downs in the foreground, rolling up to the towering bluffs in the background.

The vast acreage of national forests of western North Carolina near Asheville will be alive with carpets of beautiful wild flowers at the time of the meeting. On Craggy, above Asheville,

A leading cultural attraction in Asheville is the famed Biltmore House and Gardens, former home of the late George Vanderbilt. The landscape setting was planned by Frederick Law Olmsted, designer of Central Park in New York City.

the world's largest stand of natural rhododendron literally blankets the hillsides.

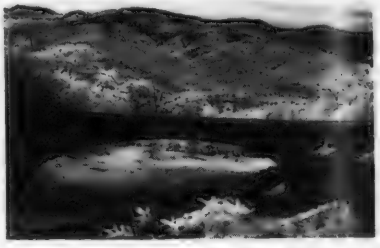
In Asheville, the leading cultural attraction is Biltmore House and Gardens, regarded as the showplace of the south. The priceless paintings, tapestries, antique vases and statues were collected by the late George Vanderbilt from all over the world. The 12,000-acre estate is considered one of the finest examples of landscape design in America.

Virtually the center of a whole handcraft region, Asheville has many shops featuring products of the painstaking

Mountain folk in the Asheville area pride themselves on their handicraft skills. Above is a hand weaver at Biltmore Industries, home of the famous Biltmore Homespun fabric.

work of the mountain folk of the area. For generations, these people have taught their young the skills of fine jewelry work, weaving, basket making, carving, and many other crafts.

At Biltmore industries, home of the famous Biltmore Homespun fabric, visitors can see all the fascinating



Buck Creek Gap on the Blue Ridge Parkway, 38 miles northeast of Asheville. In the background is the Mount Mitchell Range of the Black Mountains.

processes of woolen manufacture by hand, from fleece to finished cloth.

For the sports-minded, there are four 18-hole golf courses in and near Asheville, as well as several tennis courts and swimming pools. The mountains of the area are interlaced with clear, sparkling streams abounding with trout.

Mile-high Swinging Bridge on majestic Grandfather Mountain, said by geologists to be the oldest mountain in the world. A new highway permits driving to the crest of the most spectacular peaks in the Eastern U. S.

Cover Picture:

Champion Paper & Fibre Board Chairman to Address FPRS, June 5 at Asheville, N. C.

A pioneer in the development of voluntary forest conservation programs will be the principal speaker at the Official Luncheon Tuesday noon, June 5, during FPRS' Tenth National Meeting in Asheville, N. C. He is Reuben B. Robertson, Sr., president and chairman of the board of Champion Paper and Fibre Co., Canton, N. C.

Mr. Robertson received the American Forestry Association Distinguished Service Award in 1954 for his efforts in the development of forest conservation programs. He was cited as "one of the pioneer industrialists whose long, patient, unrelenting interest and participation in better forest management have helped to lay the foundation upon which industrial forestry has attained its present structure."

Lauding Mr. Robertson as an outstanding example of "enlightened leadership" in industry, the citation also noted that, "Years ago, he not only had the mind, but also the will, to press for improved forestry practices and he has fathered these practices not only in North Carolina but throughout the country."

Other honors which Mr. Robertson has received include an honorary Doctor of Science degree from North Carolina State College in 1932, and his election as "Man of the South" in 1950.

A native of Cincinnati, Ohio, Mr. Robertson was graduated from Yale University in 1900 with an A.B. degree. He attended the Law School of Cincinnati and was admitted to the bar in 1903.

Mr. Robertson joined Champion Paper and Fibre Co. in 1912 as general manager and became vice-president in 1918. He was president of the firm from 1925–35, executive vice-president from 1935–45, and again served as president from 1946–50. He became chairman of the board in 1950 and his son, R. B. Robertson, Jr., was elected company president. In July 1955, the younger Robertson was appointed Deputy Secretary of Defense by President Eisenhower, so his father assumed the dual capacity of president and board chairman.

Long a leader in the field of employee relations, Mr. Robertson was cited for his efforts in an article in Business Week in August 1953. The article noted that he was one of the founders, and still a director, of the Southern Industrial Relations Conference, and "has made an impressive record in personnel and community relations."

He is past president, North Carolina Forestry Assoc.; past chairman, Southern Conference on Human Relations in Industry; past chairman, North Carolina Wood Utilization Committee of Dept. of Commerce; past president, American Pulp and Paper Assoc.; and past director, National Association of Manufacturers.

Candidates for FPRS National and Regional Posts

1956–57 President of FPRS will be Ralph H. Bescher, who automatically succeeds to the presidency. He is Manager, Wood Preserving Division, Koppers Co., Inc., Pittsburgh, Pa. A charter member of FPRS, Bescher served as North-Central Regional Board Member, 1949–52; General Chairman, 1952 National Meeting; Vice-President, 1954; President-Elect, 1955; and is Program Chairman, 1956 National Meeting.

R. H. BESCHER

F. H. KAUFERT

Elective Offices

For President-Elect—Dr. Frank H. Kaufert, Director, School of Forestry, U. of Minnesota. He was associated with DuPont Chemical Co. and U. S. Forest Products Lab before joining Minnesota faculty, formerly served as member of Council of Society of American Foresters.

W. J. EASON

J. A. HALL

For Vice-President (One to be elected)—W. Jeter Eason, Vice-President, Nickey Brothers, Inc., Memphis, Tenn.; or Dr. J. A. Hall, Director, U. S. Forest Products Laboratory, Madison, Wis. Eason is also President of architectural firm of Eason, Anthony, McKinnie and Cox, Memphis; has served as FPRS South-Central Regional Board Member, 1953–56; General Chairman, 1953 National Meeting; past Chairman of Deep South Section. Dr. Hall, former director of Pacific Northwest Forest and Range Experiment Station, served as FPRS North-Central Regional Board Member, 1952–55; was recently elected Fellow of Society of American Foresters.

For Southeast Regional Board Member, 3 Years (One to be elected)—Carl L. Brice, President, Brice Lumber Co., Archer, Fla.; or W. L. Irwin, Works Manager, Poinsett Lumber and Manufacturing Co., Pickens, S. C. Brice is Trustee of F–G–A Section, formerly served as Florida FPRS Membership Chairman. Irwin is past Chairman of Carolinas–Chesapeake Section, is Chairman of Entertainment and Meals for Tenth National Meeting in Asheville.

For South-Central Regional Board Member, 3 Years—W. R. Warner, Manager, Southern Lumber Co., Warren, Ark. He is a graduate electrical engineer, formerly was associated with Weyerhaeuser Timber Co. in Pacific Northwest.

1957 National Nominating Committee (4 to be elected)—K. G. Fensom, Superintendent, Forest Products Laboratory, Vancouver, B.C.; E. G. Locke, U. S. Forest Products Lab., Madison, Wis.; C. C. Heritage, consultant, Tacoma, Wash.; F. E. Dickinson, Director, California Forest Products Laboratory, Berkeley; C. R. Lockard, Northeastern Forest Experiment Station, Upper Darby, Pa.; W. J. Tomford, James E. Stark Lbr. Co., Memphis, Tenn.; G. A. Garratt, Dean, Yale University School of Forestry; and W. R. Smith, Southeastern Forest Experiment Station, Asheville, N. C.

Notice: Upon receipt of ballots, any member may vote for an eligible candidate of his own choice for any elective office by inserting the candidate's name on the ballot.

Three Judges Named for 1956 Wood Award Contest

Dr. A. J. Panshin, Chairman of FPRS Industry-Education Committee, has named judges for the 5th Annual Wood Award competition sponsored by Wood and Wood Products magazine, Chicago. Awards of $350 and $150 will be made for outstanding papers submitted by graduate students at North American colleges, with presentations to be made at FPRS National Meeting June 4–7 in Asheville.

Judges are Col. J. H. Jenkins, Director, Forest Products Laboratories of Canada, Ottawa; John H. Brown, Research Dept., Potlatch Forests, Inc., Lewiston, Idaho; and Chairman, H. O.

Fleischer, Technologist, U. S. Forest Products Laboratory, Madison, Wis.

Entries to date are represented from the following institutions: Idaho, Iowa State, Purdue, Yale, Michigan, Minnesota, North Carolina State, Laval (Quebec), and U. of Toronto.

Northern California Section Schedules Annual Meeting

Henry J. Vaux, Dean, California School of Forestry, will be principal evening speaker at the annual meeting of the Northern California Section April 27 in San Francisco. He will discuss Wood, Research and Economic Growth in California. Topics scheduled at an afternoon technical session include: using lignin and cellulose, utilization of redwood waste material, grading green rotary-cut veneers, and re-logging selectively cut mixed conifers.

Technical Sessions, Plant Tours Planned at Midwest Meeting

Two technical sessions and tours of four plants are program features of the Midwest Section spring meeting May 2 and 3 in the American Legion building, Dubuque, Iowa.

Speaking on the modular system of home construction will be Wayne Norman, Carr, Adams & Collier Co.; J. E. Kinnebrew, Kroehler Mfg. Co.; and F. E. O'Dowd, Edward Hines Lumber Co. Other speakers and their topics will be: A. Klemm, Monsanto Chemical Co., treated millwork; Leo Iglewski, Igloo Cabinet Co., humidifying; and O. K. Hutcheson, Central States For. Exp. Sta., timber resources in Midwest. Plant tours are scheduled to Carr, Adams & Collier, Farley & Loetscher, Northome Furniture, and insulation board plant of Barrett Division.

FPRS SCOREBOARD

We're in the home stretch with three Sections battling it out to see who will win FPRS' 1955–56 National Membership Crown. A dark horse could still slip in between now and May 31 when the polls close.

Three awards, 1st for greatest percentage gain, 2nd for greatest numerical gain, and 3rd for runnerup will be presented at the 10th National Meeting in Asheville in June. Winners last year were, respectively, Inland Empire, Northeast, and Northern California.

C'mon all you good membership chairmen, let's get in there and pitch from now 'til June!

	Members 4/29/55	Members 4/1/56	Net Gain or Loss	Wgtd. % Gain
East. Can.	176	222	46	28.1
Pac. N.W.	377	449	72	24.9
Inland Emp.	73	91	18	20.6
Pac. S.W.	54	65	11	
Mid-South	163	188	25	
No. Calif.	136	153	17	
Midwest	334	349	15	
Upper Miss.	97	100	3	
Northeast	514	518	4	
Fla.-Ga.-Ala.	103	103	0	
Car.-Ches.	234	233	—1	
Ohio Valley	95	89	—6	
Great Lakes	218	194	—24	
Overseas	160	207	47	
	2734	2961	225	
Subscribers	130	168	38	
Total	2864	3129	265	

INDUSTRY NEWS

NLMA Committee Surveying Particle Board Industry

A special NLMA committee is surveying firms interested in particle board production, testing and marketing, asking their advice on how to expand and improve operations of the industry. Burton F. Swain, Jr., president, National Veneer and Lumber Co., Seymour, Ind., heads the committee considering plans for an industry organization to deal with particle board marketing and standards problems.

Swain urges all companies or individuals interested in wood particle board to contact him so they may be included in the study. The questionnaire is seeking production figures and information on types of board manufactured, process and end-use involved, markets, and whether an industry association is needed.

Wood-Worker Magazine in Salute to U.S. Forest Products Lab

The June issue of the *Wood-Worker* will carry a vital presentation on research as it concerns the wood products field today, including advantages and pertinent shortcomings from the competitive standpoint. An analsis of previews to date indicates that every forward-looking industry member will be interested in the presentation. Facts and figures will be current, and the research story will be presented as never before. A highlight will be the tribute to the work of the U. S. Forest Products Laboratory, Madison, Wis.

While the *Wood-Worker* is available on subscription only, we understand that single copies of the June issue can be ordered in advance for 25¢, if received before May 15 by the Circulation Dept., Wood-Worker, 2232 N. Meridian St., Indianapolis, Ind. Orders may not be filled for more than a few days after publication. High demand is anticipated for this issue, and in view of the subject matter, we suggest that interested FPRS members and readers order early if they wish to be certain of having a copy of this worthwhile issue.

See Preview of National Meeting Papers Pages 33-A–35-A

Northwest Lumber Conversion Statistics

An important release brought to FPRS' attention is an advance copy of "Conversion Factors for Northwest Forest Products" from one unit to another. Prepared by the Institute of Forest Products, University of Washington, Seattle, the report will be revised as suggested by industrial managers and later published for distribution.

The data applies to commercial species, utilization methods, equipment, etc., of the Northwest Region. The introduction cautions that conversion figures may not be applicable to all plants, because of differences in equipment and methods. In cases of factors showing a divergence, several figures are given rather than an average.

Typical contents include: **I. Cord-Volume Factors:** air-space ratios for solid wood, bark; cubic foot factors per cord of different species, bark, solid; cubic foot wood content of residuals; cord-thousand board feet factors; pulpwood-cord yield by tree diameter; bolts per cord; non-standard cords. **II. Board Foot-Log Scale Factors:** log scale-volume conversions. **III. Weight Factors:** lumber and log weights, green, kiln-dried; weights of logs and piling, with bark; average weight of green logs by species; effect of log diameters on weights per thousand board feet; average weights of commercially important woods, etc.

Similar data is covered on Cubic Measure Factors, Pulpwood and Paper-Pulp Factors, Veneer and Plywood, Hogged Fuel, and Factors for Minor Forest Products, charcoal, bark, hardboard, and Pres-to-logs.

Southern Seasoning Association Plans May Meeting in Georgia

Program details have been announced for a meeting of the Southern Wood Seasoning Assoc. May 11 and 12 in Valdosta, Ga. W. R. Smith is program chairman and A. W. Skoropat is in charge of local arrangements.

Discussion topics will include: air seasoning problems, prevention of warp, proper moisture contents for various uses, moisture meters, and wholesaler's viewpoint on seasoning. Also featured will be a panel discussion by kiln operators and a tour of the Landgdale Co. plant.

Crawford of Jamestown

CRAWFORD FURNITURE MANUFACTURING CORPORATION • JAMESTOWN, NEW YORK

CHOOSES Standard PREFABRICATED DRY KILNS

And no wonder! Compared with a good masonry building, the *Standard Prefabricated Dry Kiln* cuts steam radiation losses 50% or more . . . *resulting in tremendous fuel cost savings.*

To produce uniformly-dry lumber, efficiently and economically, take a tip from the folks at Crawford. Install *Standard Prefab Kilns* now. They can be *completely* installed in any size—from a small research kiln to a large production unit—in only a few days!

Here is the *Standard Prefabricated Dry Kiln* installation at the modern Crawford factory in New Bethlehem, Pa. The sturdy building is constructed of vapor-proof, rust-proof, heavily-insulated aluminum panels which require *no maintenance*. Entire building can be quickly and easily moved to a different location whenever desired.

View of fan chamber showing *Standard's* cross-circulating, direct-driven internal fan units, properly placed to face side wall. Each ball-bearing motor is glass and silicone-insulated to withstand temperatures up to 356° F. and humidities up to 100%. Note fin pipe heating system.

Write Today for Free, Illustrated Standard Catalog

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P. O. BOX 5708 . . . . INDIANAPOLIS 21, IND.

BRANCH OFFICE: REDMAN ENGINEERING SERVICE • HIGH POINT, N. C.

Another FPRS Milestone

THIS IS A GOOD TIME to express our appreciation to the 76 firms listed below. Through FPRS' Employment Committee they have offered summer jobs to wood technology and forestry students. In so doing, they have supported the tireless efforts of Dr. Newell Norton and his colleagues in universities across the continent to set in motion an effective long-range student summer employment program.

M. B. Christian

In itself this is a noteworthy milestone in FPRS progress, but there is further significance. If you will take a closer look at these names you will note they are located in the four corners of the U. S. and in Canada. They represent not only some of the largest organizations in American industry, but some of the smallest. Finally, they include great diversification — chemicals, furniture, pulp, paper, plywood, lumber, packaging, veneer, preservation, adhesives, and others.

What a fitting tribute to the *objectives* of the Forest Products Research Society! You are witnessing, in the first year of this committee's work, magnificent testimony that companies and persons having diverse interests in wood can be spontaneously united in a common cause. When a young, 9-year old society can achieve this spirit of industry-education cooperation, there is, to my thinking, no limit to the potential progress which increasing numbers of FPRS members can bring to our industry.

I trust these companies will be patient with our efforts to provide promising young men this year, and while we may not have sufficient student-power to go around 100%, we hope they will back our efforts again in 1957 when this function will have grown bigger and better. I also hope our educators will inspire their students to seek employment with these firms this summer.

76 Companies Provide for Student Summer Jobs

Northeast: Atlas Plywood, Bakelite Corp., Cotton–Hanlon, Fyles Co., Heywood–Wakefield, Jamestown Veneer and Plywood Corp., Koppers Co., Osmose Wood Preserving Co., Protexol Corp., St. Regis Paper Co., Sensenich Corp., Stromberg–Carlson Co.

North-Central: Amos–Thompson Corp., Atlas Plywood, Brunswick–Balke–Collender, Dunbar Furniture Corp., M. B. Farrin Lbr. Co., Forest Products Mfg. Co., General Box Co., Globe–Bosse–World Furniture Corp., Goshen Mfg. Co., Hartzell Industries, Hillenbrand–Romweber Co., Edward Hines Lbr. Co., Hoosier Panel Co., Jasper Wood Products Co., Joslyn Mfg. & Supply Co., Koppers Co., Mengel Co., National Homes, National Veneer & Lbr. Co., Pierson–Hollowell Co., Radio Corp. of America, W. M. Ritter Lbr. Co., Showers Bros., Spencer Cardinal Corp., Chester B. Stem, Inc., Tell City Furniture Co., Consider H. Willett, Inc., Wood–Mosaic Co.

Northwest: J. H. Baxter & Co., Borden Co., B. C. Forest Products Ltd., Douglas Fir Plywood Assoc., Educators Mfg. Co., Elmer & Moody Co., Forest Fiber Products Co., Giustina Bros. Lbr. Co., Harbor Plywood, C. D. Johnson Lbr. Co., MacMillan & Bloedel Ltd., Medford Corp., Monsanto Chemical Co., Moore Dry Kiln Co., J. Neils Lbr. Co., Northwest Door Co., Pope & Talbot, Reichhold Chemicals, Roseburg Lbr. Co., Seattle Door Co., Simpson Logging Co., Snellstrom Lbr. Co., Western Pine Assoc., West Tacoma Newsprint Co., Willamette National Lbr. Co., Willamette Valley Lbr. Co.

Southwest: Associated Lumber & Box Co., Cloverdale Redwood Co., Eureka Redwood Lumber Co., Evju Products Co., Hammond Lumber Co., Los Angeles Period Furniture Co., Pine Mountain Lumber Co., Rockport Redwood Co., Sacramento Box & Lumber Co., U. S. Plywood Corp.

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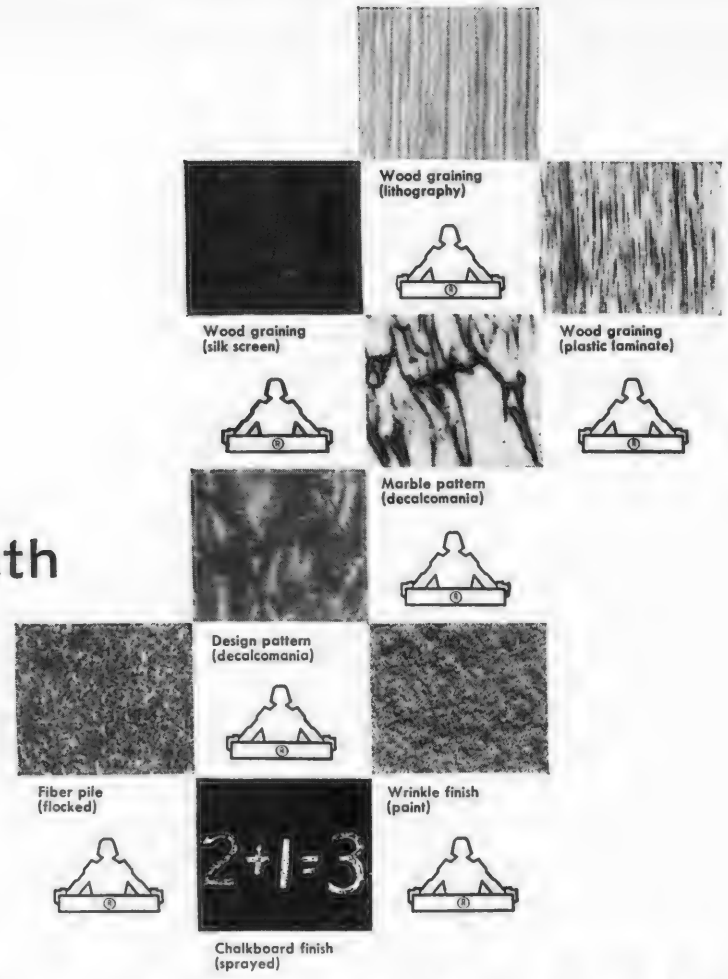

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Relationship of Research in Forest Products and Forestry

DE WITT NELSON

President, Society of American Foresters; and Director, California Department of Natural Resources

WITHOUT QUESTION THE EXISTENCE of the forestry profession is dependent upon the demand for and use of forest products. The corollary is also obviously true that the forest products industry is dependent upon forestry. The field of forestry encompasses such things as the establishment of forests, their protection from fire, insects, disease, and other pests. It also includes management planning, silvicultural treatment, harvesting methods, and many other steps necessary to produce wood. Because a large part of timber products still comes from the plentiful, virgin forests that we inherited from nature, there sometimes is a tendency to forget that forests are a crop that must be sown, nurtured, harvested, and regenerated in order to satisfy our wood needs.

A clear understanding and appreciation of this interdependence between the forest products field and the forestry profession is necessary. In managing lands, foresters cannot lose sight of the fact that the primary use of most forests is to produce usable wood products and they must be governed accordingly. Foresters who thoroughly understand the forest products industry and the workings of its economy not only are better foresters, but they are better equipped to produce the raw material needs of the wood industry. Forest products workers at all levels—management and labor, research and production, and promotion and sales—likewise have a direct interest in and depend upon the forester's job.

Research Insures and Expands Markets

The need for research in all human endeavor to keep pace with a growing population and expanding economy is being recognized more and more. The frontiers that remain today largely lie in the quest for knowledge and in technological progress. Unfortunately, research probably is accepted more in other activities than in forestry. A study of "Forestry and Related Research in North America"[1] conducted in 1953 by the National Research Council and the Society of American Foresters, sponsored by the Rockefeller Foundation, showed that most industries competitive with timber products are investing at least 1% of gross product value in research. A 1% of products value figure is about the minimum that forward-looking enterprises should be investing in research to insure and expand markets for their products. The present total investment of $40.8 million in forest products and timber production research is equivalent to only .31% of the $13 billion timber products value.

Members of the Forest Products Research Society and others connected with the manufacture and use of wood products are particularly concerned with forest products and utilization research. Here the picture is more encouraging, although it is readily apparent that the level of investment may still be inadequate.

The study previously mentioned indicated that forest products and ultilization research amounts to one-fourth of 1 per cent of the total timber products value. The present research effort in forest products is worth $31 million in an industry having a $13 billion product value. The remarkable fact about this investment is that over $26.5 million, or some 85%, has been expended by private industries. In 1952 there were almost 1,700 organizations engaged or interested in forest products research, only 125 of which were supported by public agencies. Over 11,000 forest products research projects were under investigation by all agencies in 1952.

The pulp, paper, and other fiber products fields far outled lumber, peeled wood, preservation, and other wood fields in amounts expended for forest products research in 1953, according to the joint National Research Council and SAF survey. Well over half of forest products research expenditures were in the wood fiber field; the others were ranked as follows: lumber, plywood and veneer, and wood preservation.

To maintain present markets for wood products, to effect better utilization of our forest resource, to meet increasing demands for fiber, building materials, and for countless other uses, there is reason for more and better research in forest products. An immediate and modest goal, according to the above study, would be to increase research effort to a point where total investments approximate 1% of value of products. This would require a four-fold increase in present effort, or in other words, to a level of $125 million.

Timber Production Research Is Vital

In order to sustain or increase the supplies of forest products required by our economy, the matter of timber production in terms of growing wood cannot be overlooked. If such is not true today, certainly growing timber as a crop will become essential if we are to meet the raw material demands by the forest products industry. When we investigate what is being done in timber production research, the report shows a less impressive picture than that in the forest products field.

Expenditures for timber production research in 1953 by all agencies amounted to $9.8 million, far less than what was spent in forest products research. Timber production investigations include many basic sciences, management, and protection. All these are vital to the knowledge and skills in growing wood crops. In contrast to forest products discussed above, expenditures for research in timber production was largely by public agencies with private projects comprising only 15% of the total effort in 1953.

If we can accept the fact that timber production must come before wood products can be processed, sold, and used, it would seem that there is some lack of balance in research effort between growing the raw material and making useful products from it. There also appears to be an inequitable

(Continued on page 20–A)

[1] Forestry and Related Research in North America. 1955. F. H. Kaufert and W. H. Cummings. Society of American Foresters, Washington, D. C.

The Author: DeWitt Nelson, a forestry graduate of Iowa State College, served for 20 years with the U. S. Forest Service, starting as a timber scaler and working up to supervisor of Shasta, Tahoe, and San Bernardino National Forests. In 1944 he was named deputy director of the California Department of Natural Resources, became state forester in 1945, and was promoted to his present position in 1953. Elected President of SAF for 1956– in December, Mr. Nelson previously served as vice-president of that Society during 1954–55.

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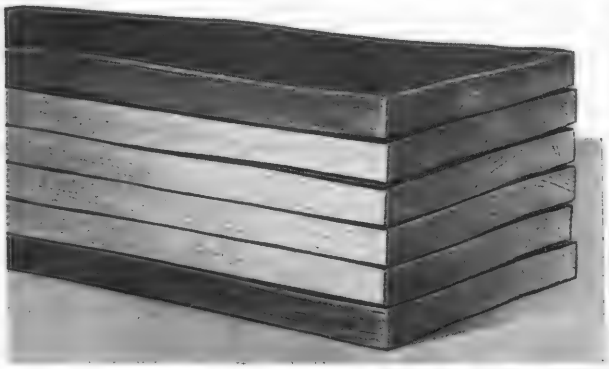
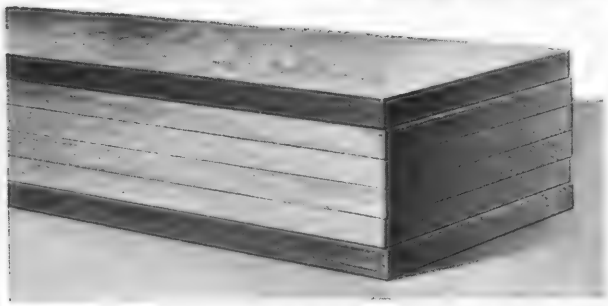


BEFORE AND AFTER



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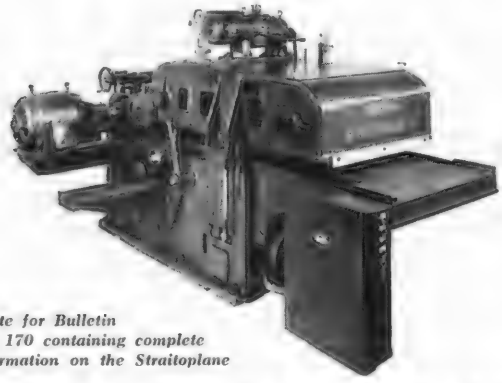

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Research Relationship

(Continued from page 19–A)

sharing of costs of timber production research when public expenditures for it, most of it federal, are over five times that from private sources. The report of the National Research Council and SAF recommends a 5.6 times increase in timber production research. This would raise the level of research expenditure to a $55 million level. This seems to be quite conservative when analyzed in terms of value that timber production research is expected to insure, develop, and protect. The conservatism of this recommendation is more striking when it is compared to what is proposed for forest products research—$125 million. This does not mean that timber production research should be enhanced at the expense of such efforts in the field of forest products and utilization, but it does suggest that timber production research efforts should expand at a somewhat more increased rate with forest products research.

The Weyerhaeuser report, made by the Stanford Research Institute, and the Timber Resource Review show that cut and growth of our forests are being brought into balance, and that there is a strong potentiality for dynamic, expanding wood markets. Moreover, although per capita consumption of lumber products may tend to decrease, there is every indication that wood will be in increasing demand because of our rapidly expanding population and the rising per capita consumption of wood fiber products by a growing population. The challenge at hand to foresters and the forest products industries is not simply to make growth and drain equal, but to make America's 489 million acres of commercial forest land produce more than currently essential and thus create a reserve to meet the growing demands. A well-balanced program of research in timber production as well as in forest products is vital to the attainment of that goal.

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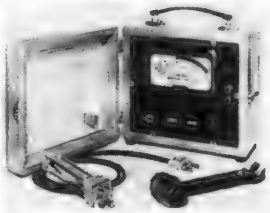

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FPRS Forest Products Journal

Vol. VI, No. 4
April, 1956

Handbook for Small Sawmill Operators

How to Attain and Maintain Accuracy of Cutting

Part I. Machinery

MILTON H. MATER
Mater Machine Works, Corvallis, Oregon
and
ERNEST CLEVENGER
Corley Manufacturing Co., Chattanooga, Tenn.

Sawmill machinery must be properly installed and maintained in order to consistently produce accurately sized lumber. With a standard circular headrig, product accuracy is particularly affected by parts of the husk, ways, and carriage, and inadequate power. These factors are discussed, as well as power requirements and corrective measures for inadequately powered mills.

Types of Headrigs

A VARIETY OF TYPES OF HEADRIGS are used by sawmills in the "small sawmill" classification. They include circular mills, band mills, sash gangs, short log bolters, double circular sawmills, and other lesser used types. Fully 95 per cent of the production of this mill class, however, is coming from standard circular mills, with the log dogged to a carriage passed back and forth by the saw (Fig. 4). Consequently, this is the type of mill with which this Handbook will be concerned.

There are a number of variations in this so-called standard type of sawmill. Most sawmills use a log carriage which mounts two or more "headblocks and knees"; secondarily, a "log beam" carriage is also used in some sections of the country. In the head block and knee type (Fig. 5), the knees support the log from behind and are mounted independently on headblocks, with the impulses from the setworks coming to the knees separately through a setshaft. This is by far the most common type of carriage, used almost entirely in heavier mills throughout the country, and in most of the lighter mills everywhere except in New England and eastern Canada.

In the log beam mill (Fig. 6), used in these latter sections, the knees are mounted in line on a heavy beam which generally receives its impulses from the setworks from pinions actuating racks at the two ends. Both types, of course, are capable of sawing accurate lumber when properly built, maintained, and operated. The log beam is usually provided with a greater number of knees, and it is claimed that this provides better support for slim and springy logs. This is especially true when such logs are straight or cants are not being taper sawed. Different types of dogs are used on the two types of carriage.

The carriage feedworks, which control the movement of the carriage in the cutting and return operation, may be powered from the mandrel, or from an independent electric motor, air motor, steam engine, or hydraulic pump. If power is taken from the mandrel it may be by means of belts, friction drums, or other mechanism. Setworks, dogs, and power sources similarly may be powered by a variety of methods. Choice among them will depend on their relative reliability and availability, the preference of the operator, the type of logs to be sawed, the products to be obtained, productivity expected, financial considerations, and relative cost of labor.

Those features which affect accuracy are discussed in the following paragraphs.

The Authors: M. H. Mater is the managing owner of Mater Machine Works, sawmill machinery manufacturers, and Mater Engineering, consulting engineers. A licensed mechanical engineer, he has written more than 35 papers on sawmill modernization and related subjects. Mater is Chairman of the Logging Division, FPRS Logging and Milling Committee.

Ernest A. Clevenger attended Chattanooga colleges, joined Corley Manufacturing Co. in 1929 and is now Vice-President. The Corley Co., a major producer of small sawmill equipment in the East, has been a pioneer in development of automatic sawmill equipment.

PREFACE

The Handbook for Small Sawmill Operators was prepared by the Logging and Milling Committee of FPRS at the request of Sectional Committee B–66 of the American Society of Mechanical Engineers.

The material has been divided into six parts being published serially in the Forest Products Journal. It will be available later as a separate bulletin from the Standards Department of ASME, 29 West 39th St., New York 18, N. Y.

Publication of this Handbook by FPRS and ASME is not to be construed as establishing any new dimensional standards for lumber. Such standards are promulgated by the American Lumber Standards Committee for softwoods and by the National Hardwood Lumber Association for hardwoods. It is designed specifically to show the small sawmill operator how he can produce lumber to those standards more economically and most efficiently.

Acknowledgment is due many people, representing the several groups interested in the small sawmill business in various ways, for the constructive help and advice given in this handbook compilation. The Committee is very grateful to all those who helped so generously.

FRED C. SIMMONS, *Chairman*
FPRS Logging and Milling Committee

Husk

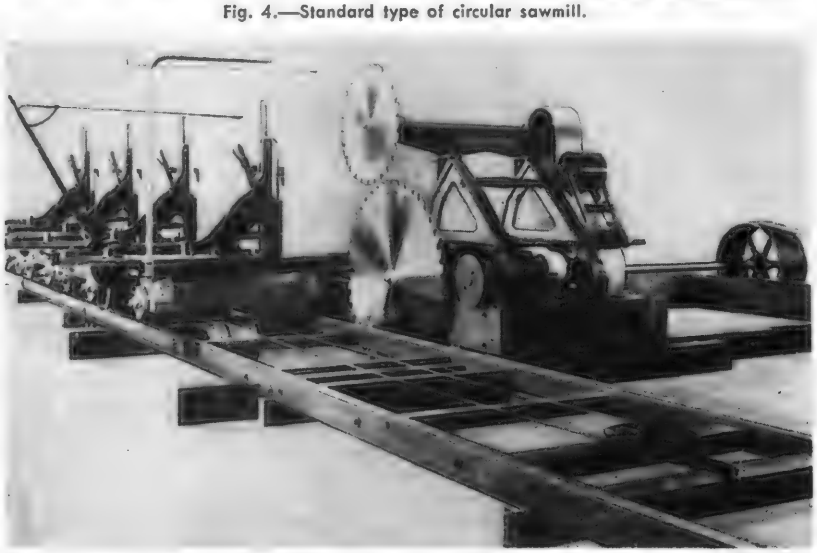
The part of the husk (Fig. 7) which has the greatest effect on accuracy of product is the mandrel, with its bearings and attached saw collar. If the mandrel is not sufficiently sturdy, accurate, and smooth running, the saw mill not run true. The minimum diameter for a satisfactory mandrel in a standard circular mill is about 2-7/16 inches. The mandrel must be straight, of a good grade of cold-rolled steel, and well supported.

Practically all mills these days have anti-friction bearings, usually of the roller or ball bearing type, on the mandrel. These should be self-aligning, and provision should be made for shifting them to give proper lead to the saw. If the mandrel is over 6 feet long, three bearings should be provided, with provision for shifting them to give proper alignment also.

While several makes of small mills use fixed ball or roller bearings on the mandrel, which allow no end play, mills with greater cutting speeds and higher horsepowers find that heating of the saws and mandrel becomes a problem. In ordinary mechanical line shaft practice, the bearing next to the collar is fixed and allows no movement of the mandrel; the other bearings are an expansion type which allow the thermal expansion of the shaft free play.

—Photo courtesy The Enterprise Co.

Fig. 4.—Standard type of circular sawmill.



—Photo courtesy Frick Co.

Fig. 5.—Headblock and knee type of standard circular sawmill.

—Photo courtesy Lane Co.

Fig. 6.—Log beam type of standard circular sawmill.

In high-production circular mills, three expansion-type bearings are often used, on the theory that the saw guide will keep the edge of the saw in line; when the saw heats, the eye will move because of the expansion, moving the whole arbor back and forth. It should be noted that in the days when babbit bearings were universally used on saw mandrels, the collars on the bearings always loosened themselves enough to allow this latter type of end play.

It is also important that the saw collar (Fig. 8) be accurately ground, of sufficient size, and tightly seated on the mandrel. Most standard headsaws are provided with a 2-inch eye, and two 5/8-inch lug pin holes centered on a 3-inch circle. In some of the larger sawmills, the lug pin holes may be larger and on a larger bolt circle. The eye of the saw should provide a good sliding fit on the mandrel, but the lug pin holes can be slightly oversize without harm, as long as the saw plate has a good bearing on them each time before the loose collar is tightened.

Collars at least 10 per cent of saw diameter help to control saw "flutter". The outer 5/8 to 3/4 inch of each collar face should be tapered to fit the increasing thickness of the saw as it changes gage approaching the eye. Taper is usually .002″ to .007″ per inch, depending on the gage change of the saw. Inside this tapered face, the collar face should be dished to about 1/32 inch concave. See Fig. 8-A. There should be no burrs around the lug pin holes. "Papering" the saw to make it stand straight on the log side is discussed under "Saws."

If the mill is apt to be somewhat underpowered, for an occasional deep cut, a flywheel can be hung on the mandrel to help overcome this power deficiency. If so, mandrel bearings must be heavy enough to support it, and the flywheel itself must be well balanced, and structurally strong so that there will be no danger of it coming apart in use. A shrunk-on steel tire is good protection against this on a cast iron flywheel.

In general the type of feedworks used does not affect accuracy of product appreciably as long as they do not put undue strain on the mandrel and they transmit power to feed and gig the carriage smoothly, without jerks and slowing down. The cables should be attached to the carriage as nearly in line as possible. If one cable is attached too far toward the 'V' wheels while the other is attached close to the flat wheels, it may cause a twist or racking

in a light framed carriage when it meets the resistance of the saw.

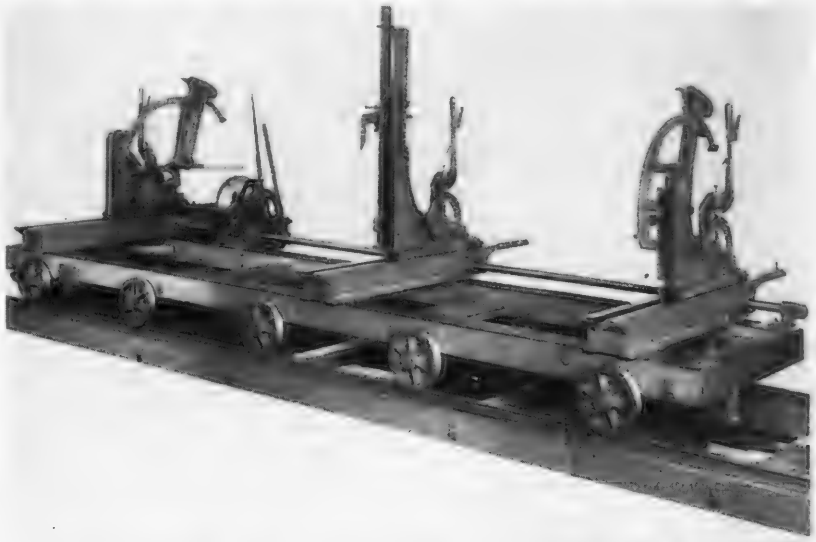
Also mounted on the husk are the saw guide and the splitter. The guide (Fig. 8) is intended only to keep the saw in line. The guide should be mounted at the front edge of the saw as close as possible to the top of the carriage headblocks. Provision for adjustment of the whole guide safely while the saw is running at rated speed is an excellent feature. Adjustment of the guide pins themselves is made while the saw is standing still. The saw should not ride against either of the pins, but just clear them when it is running smoothly at the correct speed.

Some form of splitter to keep the saw kerf open beyond the saw is required by law in many states. Even if not required, it is excellent insurance against the danger of "kick backs". Two general types of splitters are in general use: the knife type, which consists of a straight vertical blade attached to the saw husk in line with the saw; and the circular type which consists of a disk fastened to the end of a roll, which in turn is mounted in bearings on the saw husk in such a way that the board or slab rolls on the roller, while the disk keeps it from closing the kerf and binding the saw.

Ways

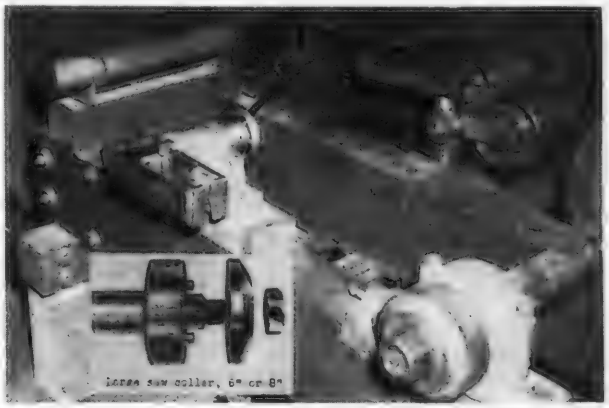
The foundation under the ways on which the carriage rides will be discussed under mill setup. It is essential that this foundation be firm, level, and true, and kept in proper relationship with the husk. Steel or wooden ways are provided by most manufacturers of very small mills, with instructions for their proper installation. For larger mills, the mill operator generally provides his own ways and installs the track provided on them. This track, of course, must be perfectly straight and true. If it develops kinks or curves due to accident or moving, it is almost impossible to straighten it by home methods. A new section should be purchased, or a factory straightening job done.

The heavier the rail, the less likely it is to develop troubles. It is essential that it be machined accurately to fit the type of carriage wheels provided. Generally, placing the guide rail at the back of the carriage, farthest from the sawyer, will prove best since it will be less likely to accumulate trash and dirt that will cause carriage jumping and inaccuracies. Location of the guide rail at the back is particularly necessary in mills using mechanical log turners. Otherwise the carriage may be derailed by action of the turner. Effective track cleaners should be provided on the



—Photo courtesy The Enterprise Co.

Fig. 9.—Headblock type of sawmill carriage. Note that in this instance, guide rails are provided on both the log and back side, but the carriage wheels on the log side have 1/16-inch clearance to allow for irregularities.



—Photo courtesy Corley Manufacturing Co.

Fig. 8.—Saw collar, saw guide, and board roll on front of husk. Note that saw guide has provision for remote adjustment.

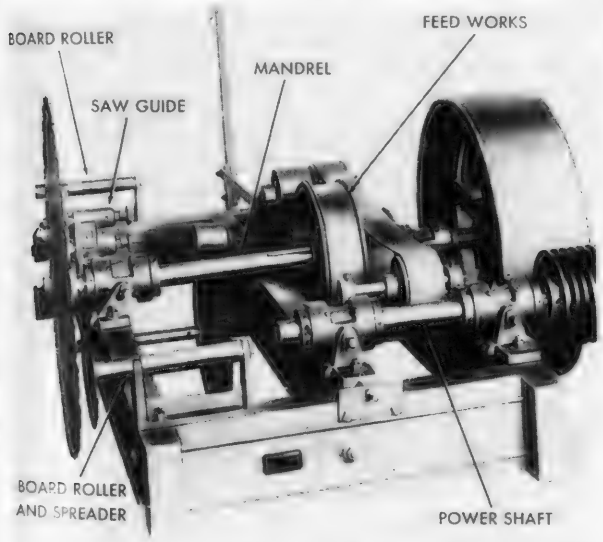


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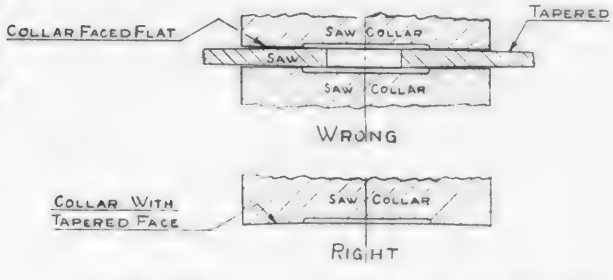
Fig. 7.—Husk of standard circular sawmill.

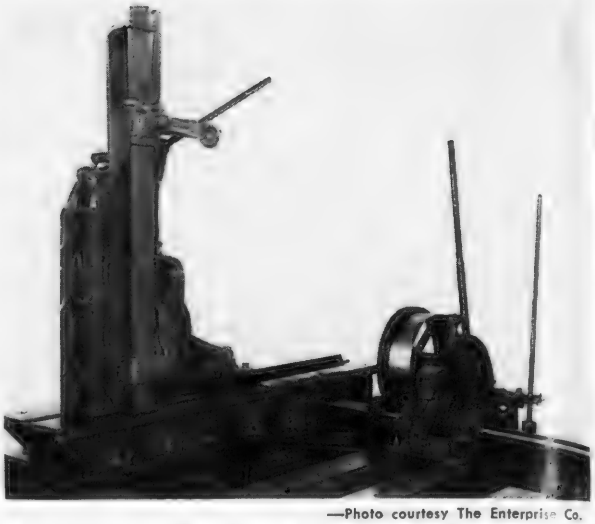


FACE OF BOTH COLLARS SHOULD BE TAPER FINISHED TO MATCH OR BE GREATER THAN TAPER IN SAW.

Fig. 8–A.—Correct taper of saw collars.

—Photo courtesy Forest Products Laboratories of Canada

Fig. 10.—Spring-loaded pressure cylinder to eliminate backlash in small mills. This is mounted on a log beam mill.



—Photo courtesy The Enterprise Co.

Fig. 11.—Headblock mill knee equipped with both standard hook dog and boss dogs. Setworks are at right.

carriage in any case. Guide rails both front and back are not recommended. Wheels on one side should "float".

Carriage

The carriage (Fig. 9) should, of course, be sufficiently large and sturdy to accommodate the size of logs to be sawed. The wheels should be machined perfectly round and true, to fit the type of track used, and there should be provision for taking up any wear that occurs in the wheel bearings to eliminate the possibility of end play developing.

Greater strength in the carriage frame is particularly necessary when a mechanical log turner is used since these devices necessarily put more shock and strain on this portion of the mill.

Sufficient headblocks and knees should be provided to firmly support the type of logs to be handled. As mentioned under "Types of Mills," slim and limber logs need more support than heavy and stiff ones. Headblocks and knees should be spaced so that the overhang on each end of the carriage should be limited to not more than four feet on medium and large logs and two feet on very small logs. Tapers should be placed on all knees preferably, and on the first and third knees, on a three block carriage, as a minimum.

It is particularly important that worn headblocks and knees be replaced or remachined so that the knees are not thrown out of horizontal and particularly of vertical alignment. Many of the more expensive knees and headblocks are provided with reversible and replaceable wearing slide strips. If present, they should be adjusted and tightened when looseness is detected. To test knee and headblock wear, grasp knee at the top and push it forward and backward; if it can be pushed much more than 1/32", it needs adjustment or repair.

Backlash in the connection between the knees and the setworks shaft is a common ailment, particularly in the less expensive mills, even when they are new. If the knee can be moved forward and backward in its slide while the setworks remain stationary, backlash is present and inaccurately cut lumber is certain to be the result.

Means of backlash takeup are provided on most rack-and-pinion headblocks and knees. Usually the setworks shaft and pinions are raised to better mesh with the rack. A pressure cylinder device which aids the removal of backlash in very small log mills has been designed and tested by the Forest Products Laboratory at Ottawa, Ontario (Fig. 10). A bulletin describing this device, which is known as an Adjustable Sawmilling Gage, is available from the above address.

Dogging devices also must be kept in good condition and used properly. As mentioned previously, a tremendous variety of dogs is available (Fig. 11). The points on all of them have to be kept sharp, and maintain the proper shape to hold the log firmly against the knee or it will shift in sawing and inaccurate lumber will result. The all-too-common practice of using only the front dog on small logs cannot be condemned too strongly.

The use of compressed air to operate the dogs is gaining favor, even in low production sawmills. When an air cylinder does the dogging, it makes for a firm grip on the log or cant, with continuous pressure during the entire cutting cycle; and it is fast and positive. Where single dogging motion dogs, such as "boss" dogs are used, it is comparatively simple to attach an activating air cylinder and valve (Fig. 11–A). Other power dogging devices in common use are electric motor operated dogs and hydraulic cylinder operated dogs.

Finally, and of greatest importance in cutting accurate lumber, is the setworks. Again a variety of types and models are available. Some of the lighter and less carefully machined hand-operated setworks are incapable of doing an accurate job even when they are new. All ratchet type setworks must be continually checked for wear on the pawls and teeth and worn parts rebuilt or replaced to maintain accuracy. Generally it is better to set to stops for the thicknesses most commonly produced, than to a visual indicator. The results attained by any system of setting should be checked periodically by actual measurement of

—Photo courtesy The Enterprise Co.

Fig. 11–A.—Headblock with boss type dogs attached to an activating air cylinder, to make dogging automatic.

the lumber produced, to make sure that the intended interval is being set.

In recent years several types of power setworks have come on the market, for different types and sizes of mills. Some of these are capable of precision setting, some are not. Also, some of these are designed to be predetermining, some are not. The predetermining type permits the setter to set for his next board while going through the cut. When the carriage returns and clears the saw, the setter activates the setworks and the knees set out a pre-determined amount and then stop automatically. In the non-predetermining type, when the carriage returns from the cut, the setter moves the knees out to his next setting by watching a scale.

Power setworks may be driven by electric motors equipped with powerful magnetic brakes for accurate stopping, electric motors driving through clutches which are disengaged when the handle comes against a stop, by air motors with fast acting shut-off valves, or by hydraulic systems operating through a hydraulic cylinder or hydraulic motor. Modern setworks have been brought to a high point of mechanization on riderless carriages on which the sawyer does the setting by pressing remote control buttons (Figs. 12 and 12–A).

All sawmills have some provision for telling the operator how much material remains in the cant on the carriage. Generally the least satisfactory is the scale on the side of the knee (Fig. 11) which is often obscured by dirt and which cannot readily be interpreted in different thicknesses. A dial indicator attached to the knee or setworks is somewhat better., Such a dial is incorporated on the large brass drum of the setworks itself shown in Fig. 11. This is calibrated to show the number of nominal sized boards left in the log after any given cut. The best and easiest to use is usually a vertical or horizontal scale board (Fig. 13) calibrated for the various thicknesses of product commonly cut.

Generally those dial indicators obtainable commercially are calibrated for an assumed average thickness of kerf 1/4 or 1/3 inch. Only a few saws actually cut these exact thicknesses, and to that degree these commercial scaleboards are inaccurate. A commercial scaleboard can be altered to a mill's individual requirements, or a completely new one built, as described in a later section.

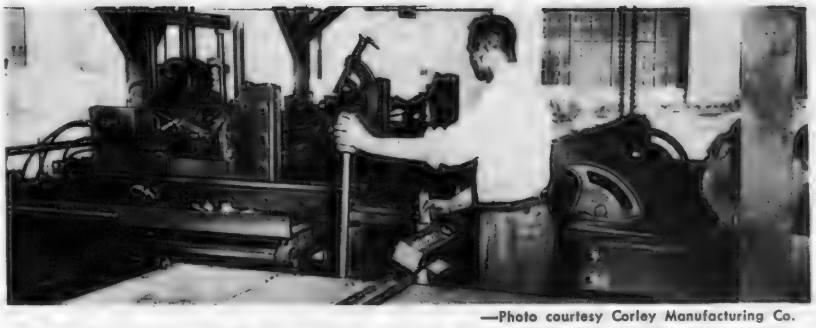
Power[1]

Not many years ago, most small sawmills were powered by steam engines. Labor to fire the boiler with sawmill residues, such as slabs, was relatively cheap, and state boiler inspection requirements were not rigid. As labor became more expensive and boiler inspection more strict, these steam-powered units have been passing out of the picture at small mills, primarily in favor of internal combustion engines.

Many millmen attempted to translate the power requirements of their mills, in terms of the rated horsepower of their former steam engines, to horsepower ratings of gasoline and diesel engines. This did not work out. The steam engines were conservatively rated, and were able to take a considerable overload. The gasoline engines, particularly those designed for use in motor vehicles, at the opposite extreme were rated at the maximum horsepower developed at the optimum speed, a speed so high that it could not be sustained in sawmill work. Consequently, a mill that operated on 25 horsepower, steam, often could not be operated satisfactorily with 60 rated horsepower in a high speed gasoline engine.

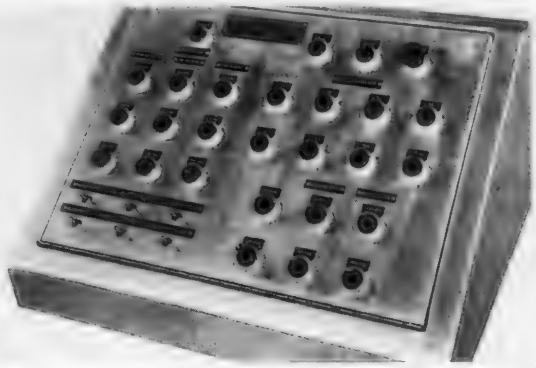
Diesel engines and slower speed, longer stroke gasoline and distillate engines, are able to deliver more nearly their rated horsepower in sawmill use. Slowing down or stalling a steam or internal combustion engine due to an overload does no particular harm to it, but it does generally result in inaccu-

[1] See table of horsepower required on the headsaw, Table 6 Appendix, and Table 5—Power Requirements of Equipment Other Than Headsaw in Small Sawmills.



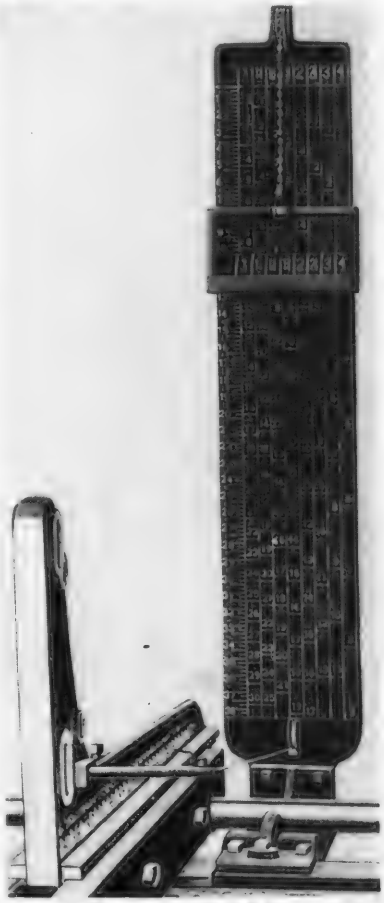
—Photo courtesy Corley Manufacturing Co.

Fig. 12.—Small sawmill for complete one-man operation. Note push button controls in front of operator for setting various thicknesses.



—Photo courtesy The Enterprise Co.

Fig. 12–A.—Push button control board for remote operation of dogging and setting by sawyer.



—Photo courtesy Corinth Machinery Co.

Fig. 13.—Vertical scale board, giving the number of cuttings of several thicknesses left in the cant.

rately cut lumber because of wavering of the saw that results.

Electric motors are now quite commonly being adopted as power sources for small mills with the extension of transmission lines into rural regions and reduction of comparative costs for electric power in many localities. Generally their horsepower output is conservatively rated by the manufacturer. An electric motor is harmed by an overload; in fact, the windings can be easily burned out in such circumstances. Consequently, a circuit breaker, with a fair factor of safety, should be installed in the power supply of any electric motor used in sawmill work.

The fairest test of whether or not a power supply is adequate to do its job in running a sawmill is by trying it. If the deepest cut expected can be made without appreciable slowing down of the saw, the power is shown to be adequate. If slowing down occurs, however, there are several measures that can be taken to correct the trouble. Power transmission equipment, including particularly all belting, should be checked to make sure that it is in good order. The power unit itself should be checked to make sure it is running at the optimum speed and is not fouled up with carbon or otherwise out of order. If no trouble is found in these directions, the power unit can be relieved of part of its load, such as auxiliary equipment (edgers, blowers, etc.), or a bigger power unit can be installed.

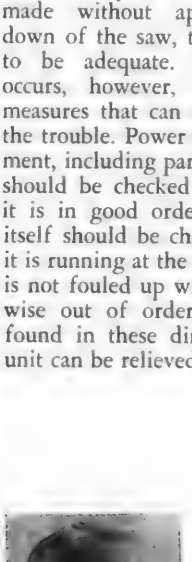
Another method of making a mill that is inadequately powered cut more accurately, frequently is to increase the depth of cut made by each saw tooth. It has been found that, within limits, taking a deeper bite does not consume more power proportional to the amount of additional work being done. The principle is the same as chopping with an ax—taking a thick chip rather than a thin one takes little if any more power on the down stroke, but somewhat more to twist out the chip.

A thicker bite per tooth may be taken by switching to a saw with fewer teeth, or by slowing down the revolutions per minute of the saw mandrel. This latter may be done by installing a bigger pulley on the power unit, or a smaller one on the mandrel. In either case the feed rate of the log into the saw may be kept constant or even increased. If the saw speed is reduced appreciably, of course the saw must be retensioned to run properly at the new speed.

There is another advantage to running the saw at slower speeds on inadequately powered mills. Coarser sawdust is made, which chambers better in the gullets and is less apt to slip by and rub between the saw plate and cut faces, causing the saw to heat and run off line. Also it has been found that falling off in saw speeds, due to a laboring power unit, is less serious in causing the saw to cut off line in saws running at slower speeds than 600 rpm than in saws at running at speeds in excess of this rate.

The limitation in the amount of bite that can be taken per tooth, of course, is the amount of sawdust that can be removed and carried out of the log in the saw gullets without clogging it. A good goal to aim for, in inadequately powered mills, is a bite per tooth equal in fractions of an inch to the number of inches in width of the cant face being sawed. In other words, for cants 8 inchesc wide, each tooth should be taking about a ⅛-inch bite. For cants 12 inches wide, each tooth should be cutting out about 1/12-inch. These rates of feed will not clog Style B, D, or #3 teeth, even in sawing hardwoods. A lesser bite will be necessary in cutting the harder woods with Style F and 2½ teeth because of the smaller gullet capacities provided.

On mills with surplus power available at the mandrel, feed rates can frequently be increased to give approximately these same bites per tooth with an increase in accuracy of cutting, as well as of production, primarily because of the coarser sawdust manufactured.



A New Method for Testing Wood Adhesives

III. Response of the Cross-Lap Specimen to Joint Defects[1]

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Glued wood specimens may not necessarily yield uniform strength data because of several factors. These include creation of flaws in the joint through physical failure to develop a complete bond. Two methods of testing the cross-lap specimen were studied against variations in configuration of flaws in the bond area and against variations in adhesive quality created by small additions of wheat flour. The breaking load appeared to be more closely related to length of the bond boundary than to bond area.

Introduction

IN THE EVALUATION OF AN ADHESIVE by means of a strength specimen, the strength observed is expected to be reasonably uniform for a given adhesive, as well as bear some consistent relationship with its inherent properties. Unfortunately, while an adhesive mixture may itself possess a high degree of uniformity, wood specimens glued with the adhesive may not necessarily yield uniform strength data.

Among the factors responsible for this situation, perhaps the more important are those associated with the nonhomogeneity of the wood, the topography of the surface, including machining inaccuracies, and other mechanical irregularities. Such factors produce variations in joint strength quite apart from the quality of the adhesive, and consequently cause difficulty in relating observed values of strength with adhesive properties. Knowledge concerning the influence of extraneous factors upon strength would appear to be pertinent to an understanding of a specimen.

The variations reflected in strength data through the operation of these

[1] Third in a series of contributed papers based on a thesis submitted in partial fulfillment of requirements for the Ph.D. degree at the University of Michigan.

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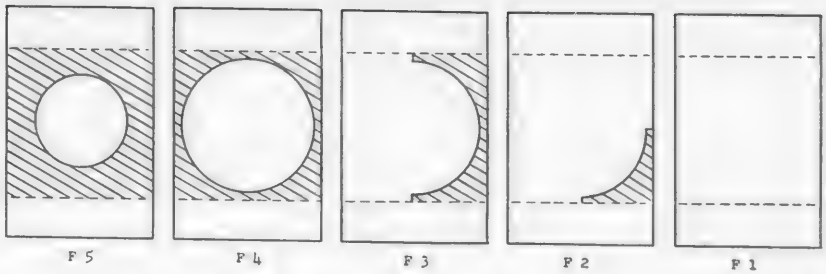
factors may be broadly characterized as resulting from two distinct actions: (1) the creation of flaws in the joint through physical failure to develop the complete bond, and (2) the contribution to the observed joint strength of the appropriate mechanical properties of the wood.

The physio-chemical condition of the wood surface, which exerts its major influence upon the degree to which the adhesive and cohesive potential is realized, is also the source of important factors affecting strength. Though not well understood, this phase of bond formation is subject to some experimental control and should not be a major cause of variation within a study. It is therefore excluded from the present categorization.

This paper deals with the first action —the presence of flaws in the joint and how they affect the observed strength of the cross-lap specimen. From the geometry of the specimen, it can be anticipated that both the size and location of flaw are likely to require investigation. The flaws in this case consisted of grease patches, of predetermined configuration, in the bond area of the specimen.

Two series of flaws were studied, one series occurring at the periphery of the joint and the other at the interior. In order to broaden the base of observations, a graded sequence of adhesive qualities (created by wheat flour extension) was super-imposed upon the peripheral series of flaws, and the resulting specimens tested by two different methods—the self-aligning grip in a Dillon Tester and the semi-rigid grips in the NAFM Glue Tester. Thus, in addition to the main objective of observing the effect of flaws on strength, an opportunity was also provided for observing the agreement between values obtained with the two methods of test, and the ability of the cross-lap specimen to reflect small increments of wheat flour. Also of interest are the relative revealing power of the two methods of test with respect to the two types of bond defects, i.e., flaws and flour, and the possible interaction of flaws with flour which might lead to means for improving the sensitivity of the test method.

The observations to be made involved not only the direct effects of several factors upon strength, but also the effect of these factors upon each other. In order to accumulate the necessary data in the most efficient manner, a statistical approach was taken. With proper sampling and control, such data may be regrouped in various ways to isolate the comparisons desired. More importantly, a measure of the degree of confidence in the results is also available.



Areas are in square inches.
Flaw areas are indicated by sloped lines.

Fig. 1.—Configuration of flaws placed in exterior locations of the cross-lap joint.

Design of Experiment

(1) Five levels of flaws (Fig. 1):

F1— 0, or no flaw
F2—¼ square inch, one-corner flaw
F3—½ square inch, two-corner flaw
F4— 1 square inch, four-corner flaw
F5— 2 square inch, four-corner flaw

(2) Four levels of adhesive quality based upon flour addition to a catalyst incorporated, powdered, urea-formaldehyde resin:

Quality 1—100 parts resin
60 parts water
Quality 2—100 parts resin
20 parts flour
80 parts water
Quality 3—100 parts resin
40 parts flour
100 parts water
Quality 4—100 parts resin
60 parts flour
130 parts water

(3) Two methods of test:

S_1—Swivel grip (Self-aligning grip on Dillion Tensile Tester)
S_2—Saddle grip (Semi-rigid grip on NAFM Glue Tester)

(4) Four replications for each combination of conditions, making a total of 160 specimens.

Making and Breaking the Specimens

The wood blocks were prepared and selected as previously described, using billets closely selected for specific gravity and conditioned to 9.4 per cent moisture content. Approximately 400 blocks were made. Of these, 128 were randomly divided into four different groups of 32 each to be given a flaw treatment, and the rest were set aside for untreated controls and for forming the other half of the specimen. Only one of the two surfaces comprising a specimen was given the flaw treatment.

All the wood blocks to be treated for flaws were then centerpricked, using a template cut for that purpose. An arc of the necessary length and radius was struck from this center using a compass carrying a sharp, soft lead. To scribe the ¼-square inch corner area, the arc of a circle enclosing 2.0 square inches was used. Since the total bond area is 3.0 square inches, such a circle would exclude 1.0 square inch of this total. By halving or quartering the circle, it was possible to define accurately the area to be treated for conditions F2 and F3. The full circles, F4 and F5, were struck to enclose 2.0 and 1.0 square inches of bond, and produce 1.0 and 2.0 square inches of flaw respectively (Fig. 1).

The flaws, or blocked areas as they may be called, were created by the application of a light grease, vasolene. The grease was applied by means of a sharpened wood spatula which permitted the spreading of a thin layer of grease to the precise area outlined. Extreme care was exercised to assure that no grease appeared on the areas which were to form the bond. A template, cut to the correct semi-circle, was used to aid in controlling the application of the grease.

After the flaw treatment, the wood blocks were immediately assembled into specimens with the designated adhesive quality levels, the adhesive being applied to the untreated surface. The specimens were assembled five per jig with each of the five flaw conditions appearing in each jig. Eight jigs of specimens for each adhesive produced eight specimens of each flaw condition.

After pressing, the jigs full of specimens were placed in a controlled humidity room to cure and condition to the original moisture content. The glue squeeze-out was removed while still soft. At the end of seven days, the specimens were randomly separated into two identical groups each having four specimens representing every combination of flaw and quality. One group was tested on a Dillon Tester using the self-aligning grips and the other group was tested on the NAFM Glue Tester with the semi-rigid grips.

Table 1.—EFFECT OF JOINT FLAWS, PER CENT WHEAT FLOUR, AND GRIP TYPE UPON CROSS-LAP SPECIMEN STRENGTH

	Breaking Load Pounds											
	Swivel Grip						Saddle Grip					
	Area of Flaw Sq. In.						Area of Flaw Sq. In.					
Per cent Flour	0	0.25	0.5	1.0	2.0	Avg.	0	0.25	0.5	1.0	2.0	Avg.	Row Average
0	1394*	1200	1139	1037	743	1103	1351	1359	1016	1028	595	1070	1086
20	1203	1290	1043	988	645	1034	1224	1252	1075	1049	539	1028	1031
40	1366	1424	1075	1116	660	1128	1340	1248	1231	1022	630	1094	1111
60	1282	1377	1045	1055	593	1070	1317	1055	952	974	629	985	1028
Average	1311	1323	1075	1050	660	1084	1308	1229	1068	1018	598	1044	1064
	Unit Stress in Pounds Per Square Inch of Bond Area												
0	464	436	456	519	743	524	450	494	407	514	595	492	508
20	401	469	417	494	645	485	408	455	430	525	539	471	478
40	455	518	430	558	660	524	447	454	492	511	630	507	516
60	427	501	418	527	593	493	439	383	381	487	629	464	479
Average	437	481	430	525	660	507	436	447	428	509	598	484	495

*Each value is the average of four observations.

In order to improve the sensitivity of the two machines and reduce the magnitude of possible reading errors, they were modified with SR-4 strain gauge systems, Figs. 2 and 3, and recalibrated against a universal testing machine.

The results were recorded in micro-inches of dynamometer deflection and then converted to pounds by use of the calibration factor determined for each machine. A summary of the results showing averages for each combination of factors is given in Table 1. Included in the table are the breaking strength values as observed, and also the unit stress obtained by converting to pounds per square inch to account for differences in bond area.[2] This table is later broken down into smaller tables of regrouped data for purposes of illustrating the various comparisons which are made.

[2] The unit stress was calculated by dividing the breaking load by the area of the bond and not by the area of the joint, which remained constant at 3.0 square inches.

Table 2.—ANALYSIS OF VARIANCE SUMMARY FOR FLAW STUDY

Source	N (SS)	DF	N (MS)	F	P
A. For breaking loads					
Total	1,975,348,791	159			
Subtotals	1,648,355,871	39			
Quality	32,837,451	3	10,945,817	4.02	<.01
Flaws	1,510,755,406	4	377,688,851	138.60	<.001
Grips	9,979,281	1	9,979,281	3.66	>.05 NS
Quality × Flaws	18,347,794	12	1,528,983	.....	NS
Quality × Grips	5,274,563	3	1,758,188	.....	NS
Flaws × Grips	7,683,174	4	1,920,794	.....	NS
Q × F × G	63,478,202	12	5,289,850	1.94	<.05
Error	326,992,920	120	2,724,941		
B. For values reduced to pounds per square inch					
Total	241,902,741	159			
Subtotals	172,866,592	39			
Quality	7,246,617	3	2,415,539	4.20	<.01
Flaws	139,544,125	4	34,886,031	60.64	<.001
Grips	3,424,350	1	3,424,350	5.95	<.05
Quality × Flaws	3,727,793	12	310,649	.....	NS
Quality × Grips	373,087	3	124,362	.....	NS
Flaws × Grips	3,335,616	4	833,904	1.45	>.05 NS
Q × F × G	15,215,004	12	1,267,917	2.20	<.025
Error	69,036,149	120	575,301		

Further data on the effect of varying bond areas which was accumulated as part of another experiment is presented in the section, Response of the Cross-Lap Specimen to Flaws in the Joint.

A summary of an analysis of variance is given in Table 2 for both breaking strength data and the unit strength data.

The data in Table 1 indicate clearly the high sensitivity of the cross-lap specimen toward flaws located at the periphery of the joint. The two methods of test give strikingly similar results, varying from the grand mean by only 20 pounds. Neither method of test reflected progressively the change in adhesive quality, and both methods responded similarly to the presence of flaws in the glue line although differing slightly in one respect. These and other results are discussed in the ensuing sections.

(a) Response of Cross-Lap Specimen to Flaws in Joint

I. Peripheral Flaws: For purposes of this discussion, the data of Table 1 were summarized with respect to flaws, i.e., the results for each method of test were combined in order to obtain the total reaction to the factor under study.

Fig. 2.—Dillon tensile tester and self-aligning grips, sensitized with SR-4 strain gauges.

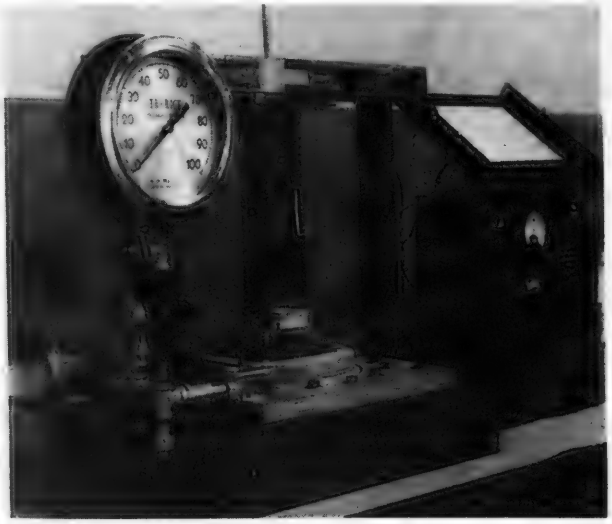


Fig. 3.—NAFM Glue Tester sensitized with SR-4 strain gauges.

Table 3.—EFFECT ON STRENGTH OF CROSS-LAP SPECIMEN PRODUCED BY FLAWS LOCATED AT PERIPHERY OF JOINT AREA

Flaw	F1	F2	F3	F4	F5
Bonded Area Sq. In.	3	2.75	2.5	2	1
Breaking Load Pounds	1310	1276	1072	1034	629
Unit Stress (PSI)	437	464	429	517	629

Table 4.—EFFECT ON STRENGTH PRODUCED BY FLAWS LOCATED AT INTERIOR PORTIONS OF CROSS-LAP JOINT AREA

Bonded area square inches	3.0	2.4	1.8	1.2	0.6
Breaking load pounds	1214*	1284	1168	1260	1195
Unit Stress (PSI)	405	535	650	1050	1992

*Each figure is the average of ten observations.

Table 5.—ANALYSIS OF VARIANCE SUMMARY FOR EFFECT OF INTERNALLY LOCATED FLAWS

Source	N (SS)	DF	N (MS)	F	P
Total	63,129,225	49			
Bond Area	4,502,850	4	1,125,712	0.86	NS
Error	58,626,375	45	1,302,808		

Table 6.—AVERAGE STRENGTH VALUES ACCUMULATED TO SHOW EFFECT OF WHEAT FLOUR ADDITIONS

Per cent Flour Extension	0	20	40	60	Avg.
Pounds Average Strength	1086	1031	1111	1028	1664
Unit Stress PSI	508	479	516	478	495

Table 3 presents the data thus accumulated. Fig. 4 is a plot of this data together with calculated representations of the manner in which the strength should have changed if it had varied in proportion to the area of bond.

While the data does not include sufficient representatives of the different types and sizes of peripheral flaws to permit generalizations on the precise effect of this factor, it is apparent some complexity in the response exists. For example, only the two-corner flaw, F3, lost strength commensurate with the loss in bond area. All others lost less strength than was predicted on the basis of the loss in bond area. Thus, the strength on a unit stress basis appears to increase as the area is decreased.

If the situation is stated in reverse, i.e., decreased unit stress with increasing bond area, the results are seen to correspond with those of deBruyne (1)[3] and others who worked with simple lap joints. Koehn (2) and more recently Yavorsky (3) have found similar situations to exist in simple cleavage specimens. It should be noted, however, that in the case of a simple lap joint, the observed strength must become asymptotic at the point where the bond area produces load-bearing capacity equal to or greater than the tensile strength of the adherend. In the cross-lap specimens, and perhaps also in cleavage specimens, the limitation of adherend strength would appear to be constant.

Despite fundamental differences in the load bearing mechanism of different specimens, investigators invariably reach the same conclusion regarding bond area, namely, that it is not the sole determinate of the strength of a joint. Ultimately it is found that certain elements of the dimensions are more important than others. This suggests the importance of bond boundary and leads to the conclusion that the edges rather than the center portions of a joint may largely determine the strength.

Further confirmation of the influence of bond boundary is evident from the present data, and also from the data of the following section in which the bond boundary was held constant but the bond area was varied. If the breaking loads are plotted as a function of the actual length of the bond boundaries, a fairly good line passing through the origin results, Fig. 5. It can be seen also that reducing the load to pounds per lineal inch of bond boundary yields a line which is nearly horizontal, indicating the close relationship of such a unit of strength with length of bond. The suggestion ensues that a factor representing the edges of a bond in the cross-lap specimen appears to provide a better means of estimating changes in strength due to changes in size of the bond than a factor representing area. Pending further tests to substantiate this inference, the cross-lap specimen may more properly be regarded as a multiple cleavage specimen than a simple tensile specimen.

The points plotted in Fig. 4 have been related by straight lines. The plots of breaking load as a function of area and as a function of length, however, cannot both be represented by straight lines since the length does not change at the same rate as area. If it is taken that the boundary length of a bond in the cross-lap specimen is

[3] Numbers in parentheses refer to literature cited.

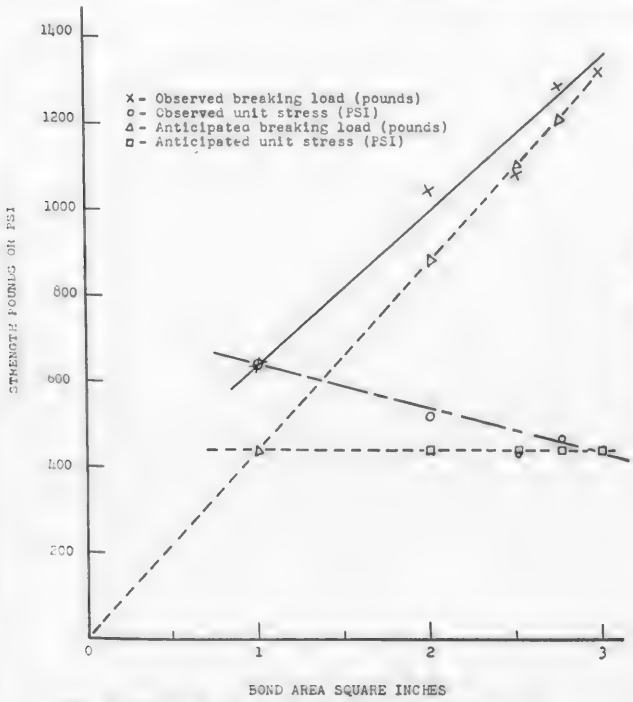


Fig. 4.—Strength of cross-lap specimen in relation to peripheral joint flaws.

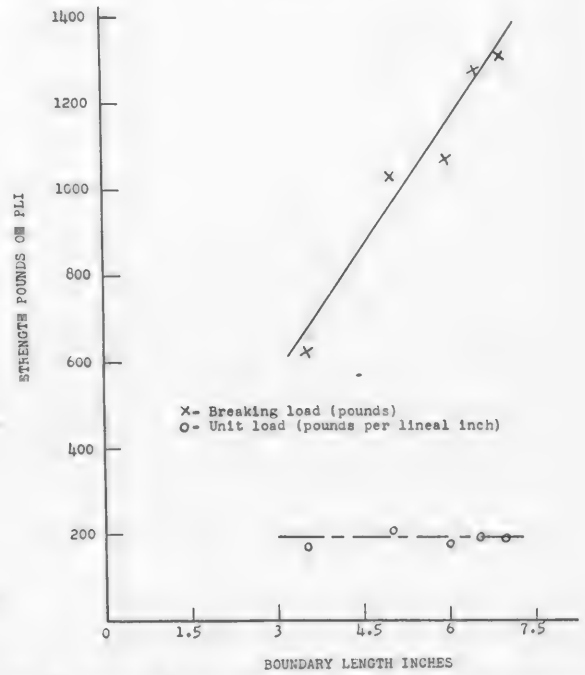
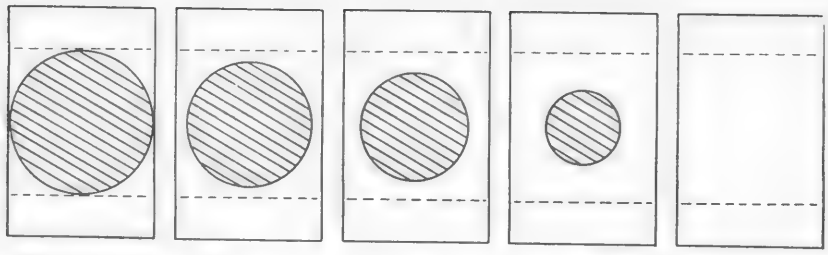


Fig. 5.—Strength of cross-lap specimen in relation to bond boundary.



Areas in square inches.
Flaw areas are indicated by sloped lines.

Fig. 6.—Configuration of flaws placed in interior locations of the joint.

a better parameter for strength than area, the area plot of Fig. 4 should in reality have been curved. This may also be justified independently. Considering that at zero bond area the strength would be zero, it must be concluded that all lines must pass through the origin. To do so would require some curving of the breaking load line and a rather sharp curve by the unit stress line of Fig. 4.

II. Interior Flaws: The preceding discussion has concerned the situation where flaws were introduced at the exterior portions of the bond area, and it was shown that the specimen responded strongly to the changes in bond area. It is of interest to compare these results with those in which the flaw was introduced at the interior of the bond area. In this case the flaws consisted of circular areas varying in diameter from the center outward. The area of flaw was varied in even increments of 0.6 square inches, giving five levels of flaws, 0, 0.6, 1.2, 1.8, and 2.4. These flaws thus corresponded to bonded areas of 3.0, 2.4, 1.8, 1.2 and 0.6 square inches respectively, Fig. 6.

Ten specimens for each bond area were made and tested in a manner similar to previous experiments. The results obtained are given in Table 4 using the averages of the 10 specimens. The data is plotted in Fig. 7 as it was in Fig. 4, i.e., as a function of area.

An analysis of variance test, Table 5, indicated that no additional variation was introduced by varying the bond area in this manner. The data for breaking load may be plotted as a straight horizontal line through the grand mean of 1,224 pounds.

It is evident that the cross-lap specimen possesses a remarkable insensitivity to flaws covering a major portion of the interior of the joint area. This is in marked contrast to the situation where the flaws are located at the exterior of the joint area. The conclusion is inescapable that the corners and edges of the cross-lap specimen are its main source of joint strength. When these fail, the rest of the joint area also fails whether a bond is present or not.

These results point to an extremely high level of stress concentration operating in the cross-lap specimen. As can be observed in Fig. 7, the unit stress rises sharply as the bond area decreases. While it must eventually fall to zero when the bond area reaches zero, it shows no sign of doing so at an area of 0.6 square inches. At this point the unit stress is 2,000 pounds per square inch, and it appears safe to predict that a peak stress considerably higher may exist before the drop to the origin.

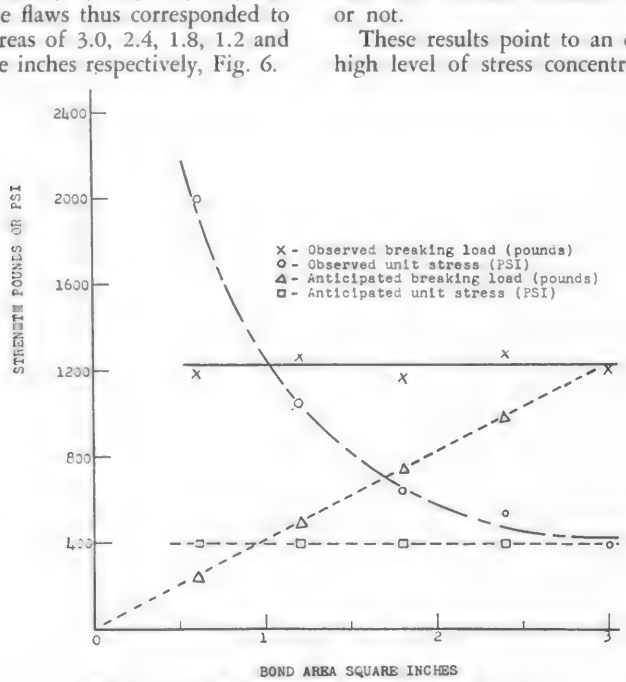


Fig. 7.—Strength of cross-lap specimen in relation to interior joint flaws.

On the basis of a unit stress of 2,000 pounds per square inch, the theoretical maximum strength of the cross-lap specimen glued with the adhesive used would be 6,000 pounds. At a failing load of 1,200 pounds, this represents a stress concentration factor of five. In other words, 80 per cent of the strength of the joint is unrealized due to stress concentration.

Apart from the relationship of observed strength to area of bond *per se* is the question of how fortuitous defects in the bond area, such as represented by the flaws included in this study, might affect an estimation of the quality of a joint if the presence and magnitude of the flaws were unknown. An appraisal of the data would lead to the conclusion that large amounts of the internal bond area might be defective without change in an estimation. Likewise, the presence of a defect in one corner of the joint may go unnoticed. The presence of external flaws greater than one corner would, however, seriously affect the strength and would introduce a high degree of error in the observation of other factors.

(b) Response of Cross-Lap Specimen to Variations in Wheat Flour Extension

To show the effect of flour extension, the data of Table 1 was accumulated horizontally, providing 40 specimens for each average representing levels of extension or quality. It is evident from Table 6 that no uniform graduation in strength occurred; the means, in fact, appear to be somewhat the same. The statistical analysis, however, indicated that a real difference existed between the formulations.

The situation thus seems to be that the cross-lap specimen has registered a significant difference between the formulations, but this difference is not directly attributable to the addition of flour. Evidently something besides flour affected joint strength. More experiments are needed to reveal what uncontrolled factor, such as rheological properties, may have been operating.

(c) Differences Between Methods of Test

For the direct effect of method of test, the data of Table 1 were accumu-

Table 7.—EFFECT OF METHOD OF TEST ON OBSERVED STRENGTH OF THE CROSS-LAP SPECIMEN

Method of Test	Swivel	Saddle	Average
Breaking Load	1084	1044	1064
Unit Stress	507	484	495

lated into the two vertical groups and averaged. The essence of the relationship between methods is shown in Table 7.

On the basis of the data, it would appear the two methods of test can be expected to produce identical results. This is supported by the statistical analysis since the total difference in strengths observed by the two methods was not sufficiently large to be considered significant. However some evidence that this may be a borderline conclusion can be seen in the analysis of the data after conversion to pounds per square inch. The difference between methods on the basis of unit stress appears to be too great to accept as a chance occurrence.

In view of the latter situation, it perhaps is safer to assume for the present, that a real difference between methods of test exists, at least in the presence of a flaw system such as that imposed. How much of this is due to slight differences in calibration and how much is actual response to the difference in means of applying load, remains a question. It is considered further in section (f).

(d) Effects of Flaws on Observation of Adhesive Quality

The observation of quality of the adhesive involving rather small variations requires maximum freedom from side effects introduced by defects in the bond area. There is a possibility, however, that the presence of certain types of defects in the bond may cause local stress accumulations to which the varying quality bonds might respond more decisively either in a proportionate or in a differential manner. If such were the case, the judicious placement of flaws in a joint could serve as a means of improving the sensitivity of the specimen. It was felt that an abrupt change in section occurring at a bond boundary might produce added stress concentrated directly at the edge of the bond. Incipient failures might thus be more quickly generated if any tendency toward weakness existed in the bond.

The present data offered an opportunity to observe whether flaws might have a bearing on sensitivity toward adhesive quality as affected by wheat flour. Two criteria were available for discerning this situation—the existence of: (1) an ordered arrangement of strengths corresponding to the progressive changes in flour extension, and (2) a statistically significant interaction between flaws and quality.

Neither criteria was manifest in the data and it may be concluded the type of flaws present do not accentuate the type or magnitude of adhesive weakness incorporated in the bond. It is possible however, that other flaw systems may prove effective.

(e) Observations of Adhesive Quality with the Two Methods of Test

There is little theoretical reason to suppose that one method of test would be likely to affect one level of quality any more than another level. It is difficult to visualize a property associated with changes in quality, which might be reflected as changes in strength by virtue of differential response of the grips or method of test used.

The data confirms that both grips are influenced equally by the changes in imposed quality. No interaction is statistically evident between these two factors.

It would appear that neither method of test possessed attributes which would make it particularly sensitive to adhesive quality. On this basis, there would be no advantage, or disadvantage, in selecting one or the other method. This statement, however, is subject to the qualification that while a difference in adhesive quality may have existed, a great enough difference in bond quality as reflected by strength, may not have existed.

(f) Response of Grips to Presence of Flaws

One of the important comparisons to be drawn from this experiment was whether one grip would reveal the presence of a flaw better than the other. In other words, is one grip more sensitive to flaws. The differences between grips was expected to arise from their relative flexibility, that is, from their ability to conform to a changing load distribution as the resistance of the joint became unbalanced through the operation of the flaws. The flaws incorporated in the normal bond area of the cross-lap specimen were designed to produce varying degrees of asymmetry in the joint and thus provide a means for the grips to demonstrate their sensitivity. It was expected that the swivel grip, being self-aligning, would be less likely to "sense" the presence of the one-corner flaw, F2, since it could act as if that corner had already broken and proceed to redistribute the load. The saddle grip, with two pairs of mutually rigid bearing edges, would be unable to conform to the weak corner, and no readjustment of load could occur.

The analysis of variance, carried out on the breaking load data, showed that, after removing the variation caused by the grips and flaws separately, the variation that remained and attributable to the combined effects of the two factors was not significant. This must be interpreted as indicating that the two grips responded the same to the location of flaws in the bond area. The conclusion would follow that neither grip possessed an advantage over the other.

While not statistically significant, it is of some interest to note the interaction which is indicated with respect to the one-corner flaw, F2. The self-aligning grip showed this to be 12 pounds higher than the control, while the semi-rigid grip produced a value 79 pounds lower than its control. Such action is in agreement with expectations, and leads to speculation as to whether a fuller scope of flaw treatments might provide greater opportunity to reveal differences.

(g) Effects of the Three Variables on Each Other

The effects of three or more variables on each other is usually a matter of statistical interest since it is often difficult to visualize the actions involved. In gluing, however, interactions of a high order cannot be easily discounted because of the large number of factors which can affect a given observation. While the present data were not sufficiently extensive to permit interpretations, it is possible to demonstrate in a small way how such interactions might exist.

The analysis of variance indicated that the second order interaction of adhesive quality, flaws, and methods of test was significant to less than the 5 per cent level on the basis of the breaking load data, and to less than the 2½ per cent level on the data after reducing to unit stress. There is a strong inference, therefore, that the total variance of the means cannot all be accounted for by the direct effects of quality, flaws, and method of test, nor by their first order interactions which were shown to be negligible. Some additional variation remained which may be attributed to the combined effects of the three main factors on each other, or to the effect of some other factor which had been uncontrolled in the experiment.

The interaction effects of the three main factors may take three different forms and involve the first order interactions at different levels of the third variable: (1) the effect of flaw on adhesive quality may be different with the two grips, (2) the effect of grip on adhesive quality may be different with different flaws, and (3) the effect of grip on flaws may be different at different levels of adhesive quality. Some evidence for this source of variation may be observed directly in the data of Table 1. For example, an effect of adhesive quality on the flaw x grip

interaction may be seen in the difference between F1 and F2 for each grip with quality 1 and quality 2. These differences are:

	Swivel F1–F2	Saddle F1–F2
Quality 1	+194	— 8
Quality 2	— 87	—28

This indicates that the difference produced between flaw F1 and flaw F2 by the two grips might be different for each adhesive quality.

Similarly, an effect of flaw upon the quality x grip interaction may be discerned by considering the differences between quality 1 and quality 2 for flaws F1 and F2 with each grip:

	Swivel Quality 1– Quality 2	Saddle Quality 1– Quality 2
Flaw F1	+191	+127
Flaw F2	— 90	+107

The difference between adhesive quality levels is different for each grip and for each flaw.

An effect of grips on the adhesive x flaw interaction is shown by the difference between results for the swivel and the saddle at flaws F1 and F2 with adhesive quality levels 1 and 4:

	Flaw F1 Swivel-Saddle	Flaw F2 Swivel-Saddle
Quality 1	— 43	—159
Quality 4	— 35	+322

The above analyses by differences indicate how the effect of two variables on each other is influenced by the third variable. This is disconcerting in a sense for it implies, for example, that the ability of the grips to reveal the presence of flaws depends upon the quality of the adhesive. On the other hand, a strong inference is thus supplied that, had there been a more marked strength-wise difference in quality of the bonds, it is possible that a particular grip-flaw combination would have been shown to possess a special sensitivity to quality.

Summary

In this experiment, two methods of testing the cross-lap specimen were studied against variations in configuration of flaws in the bond area and against variations in adhesive quality created by small additions of wheat flour. The design of the experiment permitted statistical evaluation of the data by a three-factor analysis of variance technique. Definite response to the presence of flaws was shown, as well as to differences in adhesive quality. The latter, however, was not in agreement with the designed variations in quality, and it must be presumed that other quality effects were also in operation, such as changes in rheological properties accompanying the addition of flour. Differences between methods of test, i.e., grips, were not very pronounced. All first order interactions were insignificant. The second order interaction, however, was of sufficient significance to indicate a strong influence of one factor upon the other two.

The variations in bond area provided an insight into the matter of stress concentration in the cross-lap specimen. When different size circular areas are prevented from bonding on the interior of the joint, no change in observed strength occurs. This indicated that the corners and edges of the specimen are chiefly responsible for the strength. Upon conversion to unit stress in recognition of the change in bond area, it was found that the stress may exceed 2,000 pounds per square inch, a value in excess of the published strength for maple wood in tension normal to the grain.

When the bond was prevented from forming at the corners and progressively inward, the breaking load was approximately proportional to the area. Some evidence toward curvilinearity, however, was evident within the limits of the data, and this suggested an approach to an asymptotic value as the area increased beyond three square inches. Upon further analysis, it was found that the breaking load appeared to be more closely related to length of the bond boundary than to area. This led to the suggestion that the cross-lap specimen might be considered a multiple cleavage specimen rather than a tension specimen.

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Some Variables Affecting the Shrinkage of Western Hemlock[1]

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The shrinkage of western hemlock was studied with a dimensional recorder which gave a continuous record of shrinkage during drying. The instrument showed that with high moisture content boards at elevated temperatures, there is a rapid rate of shrinkage at the beginning of the drying period. It also showed that the amount of shrinkage occurring above the fiber saturation point varies with initial moisture content. Accelerated shrinkage apparently does not cause an abnormal amount of degrade in the form of excessive checking.

SHRINKAGE AND SWELLING of wood with changes in moisture content have been the subject of investigation by many wood technologists. This characteristic of changing dimension with changes in atmospheric moisture has been considered one of the undesirable qualities of wood and a great deal of research has been aimed at eliminating or lessening the degree of movement in use.

Paints, varnishes, water repellants, and impregnated resins have been more or less successful in accomplishing this object after the wood is in service.

In seasoning green wood, shrinkage invariably occurs and it is the stresses set up by shrinkage that cause most of the degrade that occurs during the seasoning process. Splitting, checking, honeycombing, cupping, warping, bowing, casehardening, and loosened knots are all caused by unequal shrinkage in some degree. It is the problem of the seasoning expert to dry his lumber in

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such a manner that the stresses set up in drying are not great enough to rupture the lumber or cause distortion.

The phenomenon of shrinkage is exceedingly complicated and it is not the purpose of this paper to discuss the theories and factors which cause shrinkage. These have been ably discussed by wood technologists, physicists, and chemists in the various forest products laboratories throughout the world. Many of these theories have been published in the Journal of the Forest Products Research Society. Rather, it is the purpose of this paper to describe a technique of shrinkage measurement and to record some observations made by the Vancouver Laboratory of the Forest Products Laboratories of Canada on the shrinkage of western hemlock lumber.

It is the generally accepted concept that, in the process of drying, the movement of moisture out of the wood is associated with shrinkage only when the fiber saturation point is reached. This relationship between shrinkage and moisture content applies to individual wood fibers, but a piece of wood having innumerable fibers reacts in a different manner, since the moisture content of individual fibers may vary considerably. Little information is available, however, on the rate of shrinkage that occurs during the initial stages of drying.

Movement of moisture and shrinkage are important factors in the kiln-drying of wood. In kiln-drying, it is customary to start a schedule at a low temperature and a fairly high humidity, in order to prevent severe surface checking, and to establish a moisture gradient. This surface checking is thought to be caused by too severe shrinkage of the surface layers.

Description

In order to measure the rate and degree of shrinkage, an instrument was constructed at the Vancouver Laboratory, of the Forest Products Laboratories of Canada, which gives a continuous reading on a chart, and thus eliminates the variables of personal error and intermittent cooling of the test boards during measurement. This instrument is shown in Figs. 1 and 2 and is designed to provide flexibility for studies of dimensional change on either narrow stock or a wide panel.

Fig. 1 shows a 1- x 8- x 24-inch wood specimen mounted in a brass holding rack. The board is butted against fixed stops on one edge and held firmly against the stops by a slight pressure from two compressed springs. A steel holding frame is bolted to the walls of an experimental kiln chamber but provision for adjustment to various sizes of specimen has been made. Two brass hold-downs or pressure bars are included to help maintain control of the specimen, and cupping and twisting can be partially restricted by the tension screws above the pressure bars. Linear changes across the width are transmitted to the outside of the kiln by a pyrex linkage rod. Gravity action forces the linkage rod firmly against the edge of the specimen through a counter-weight on the pen arm.

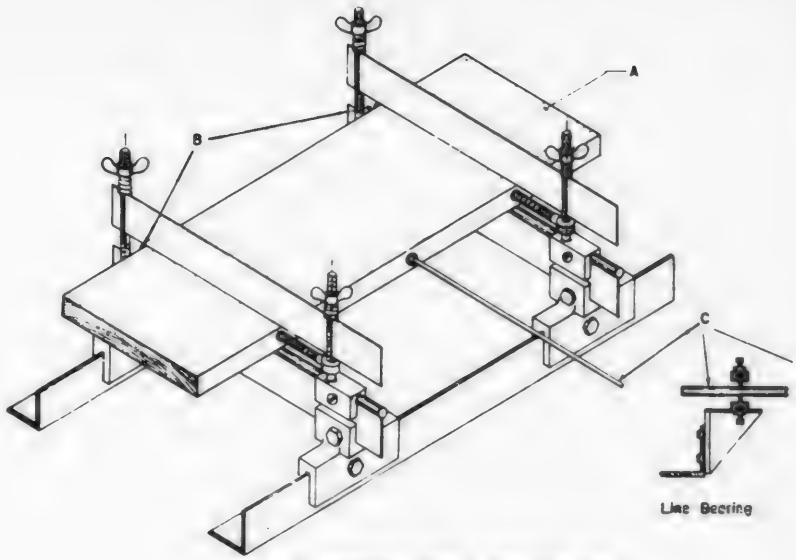


Fig. 1.—Isometric view of specimen rack.

As shown in Fig. 2, shrinkage and swelling movements are scribed on a 35- x 6-inch chart over a 7-day period. A combined adjustment unit, converter, and rotating drum are designed to magnify and record dimensional change. The pen arm pivots as a result of linear movement of the specimen and a calibrated chart allows instant reading and interpretation. Zeroing units are provided for initial orientation and subsequent resetting, if necessary. Precision control of zeroing and the magnification adjustments are made by means of threaded screws. Accuracy is to .005 inch. Calibration of measurement was made by the use of a dial micrometer reading in .001 inch. All data assembled for analysis were taken to the nearest .010 inch. As the 10¾-inch diameter drum revolves one complete turn in one week, the pen scribes the behaviour of the board and a permanent record of dimensional change is available for comparison and analysis.

For the initial study, western hemlock was selected. This wood contains a high percentage of moisture, has a high shrinkage factor (8.5 per cent tangentially), and therefore requires care in seasoning.

Procedure

Thirty individual runs were made on ten different flat-grain western hemlock boards. Six test pieces each 1- x 8- x 24 inches were cut from each board. Three of these were selected for shrinkage measurement, and the others

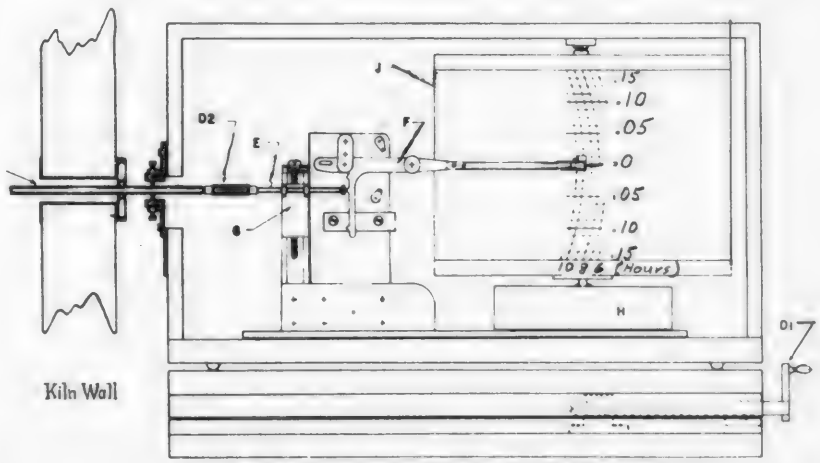


Fig. 2.—Side elevation of dimensional recorder.

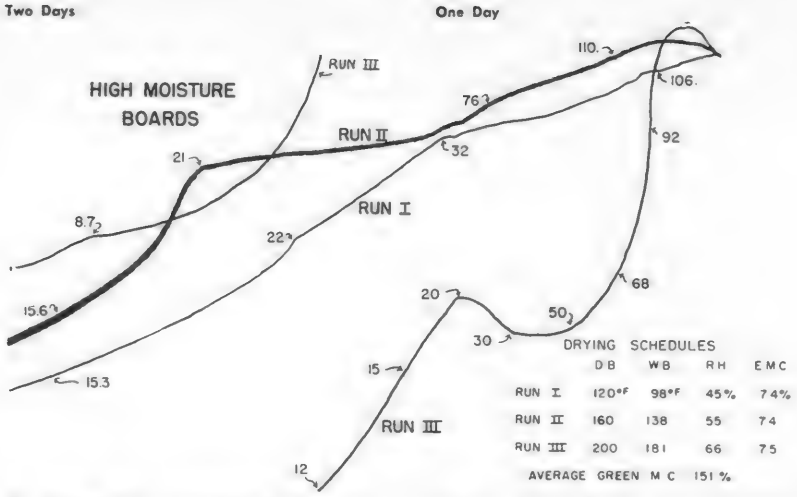


Fig. 3.—Shrinkage pattern of high moisture content piece. Note: Moisture content determinations were entered on graph after run from weight determinations.

were used as moisture content samples —two pieces comprising a set. One piece was placed on the rack of the dimensional recorder, and the other suspended from a beam and knife edge for weight determinations in a small controlled heating chamber. One end of the beam from which the sample piece was suspended was in the kiln and the other end was outside. Weights were used to balance the beam when weighings were made. Three schedules were used, as follows:

120° F.	R.H. 45%	E.M.C. 7.4
160° F.	R.H. 55%	E.M.C. 7.4
200° F.	R.H. 66%	E.M.C. 7.5

Moisture contents of the samples were determined before and during drying in the usual manner by finding the moisture content of the sample discs by the oven method and relating this to the weights of the sample.

During each run, a continuous record was kept of the shrinkage and moisture content without the necessity of cooling the samples during measurement or changing the conditions in the kiln by opening the doors. In each run the kiln was heated to the required temperature before the samples were admitted so that they were exposed to the maximum conditions almost immediately.

Fig. 3 shows a typical chart of a high moisture content test piece exposed to the three drying conditions. The figures shown represent only 48 hours' drying time.

It will be noted that there is a very small expansion at the commencement of the run. It will also be noted that with high temperatures of 200° F. there is an extremely rapid shrinkage over the first few hours. This shrinkage then ceases until the fiber saturation point is reached, after which it appears to resume normal shrinkage.

For the low and medium temperatures, the shrinkage was fairly uniform over the whole period of drying.

Although the shrinkage of the high moisture content pieces under high temperature was rapid, there was no sign of surface checking or fine hair check, even when the test pieces were viewed under a microscope. It is possible, therefore, that the wood was plastic enough at the high temperature to offset the considerable stresses that must have occurred during the initial stages of drying. It is possible also that there was a mild form of collapse in the outer fibers before a proper moisture gradient was formed. The levelling off of the shrinkage curve might indicate that a gradient had been established, and that moisture from the interior of the piece was permeating the outer cells, causing, in this particular case, a slight swelling.

Fig. 4 shows the pattern of shrinkage of a comparatively low moisture content piece of 63 per cent. Throughout the whole period of drying at each of the three temperatures used, the shrinkage curve is much more uniform than that shown in Fig. 3. There appears to be no break in the shrinkage curve when f.s.p. is reached.

The data for all runs are shown in tabular form in Table 1. For comparison, the test pieces are grouped in three moisture content classes; i.e., high, medium, and low (see Table 1). The shrinkage is also shown at 30 per cent (above the fiber saturation point) at 10 per cent, and at constant weight (E.M.C. 7.4 to 7.5 per cent).

The table shows that at all temperatures, the pieces with high initial moisture content shrink more above the fiber saturation point than do the low moisture content pieces. This is also true of the constant weight condition. There are also indications that high temperatures cause more shrinkage than low temperatures. This, however, may be due to the greater plasticity of the wood or to the higher humidity carried in order to obtain an equilibrium moisture content of 7.5 per cent. Generally, higher relative humidities cause less stress in drying, and therefore a more natural shrinkage occurs.

Both high and low moisture content pieces were case-hardened at all temperatures, but observations of checking indicated more severe defect at 120° F. The drying was slower at 120° F., and there was more uniform shrinkage. The initial severity of the drying intensity and the resulting moisture gradient as shown by the rate of drying indicate that low temperature drying of hemlock extends the period in which stress is critical.

The following table was prepared for the purpose of showing comparisons between the weight of water per cubic foot of wood and the volumetric shrinkage of some of the most common British Columbian species.

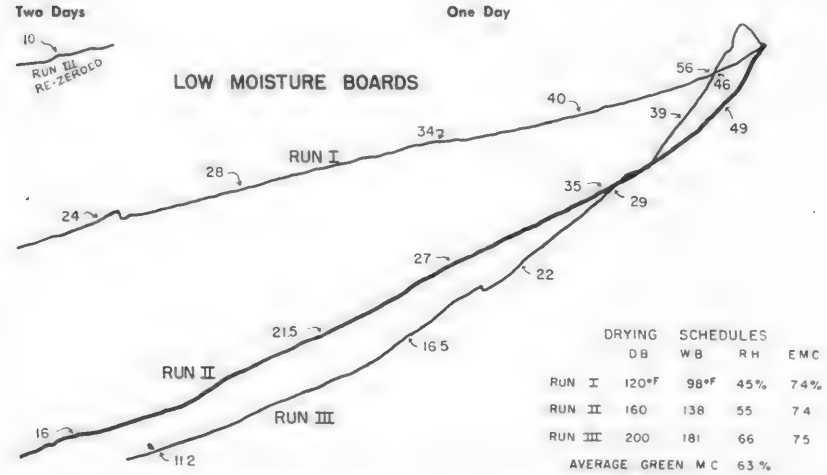


Fig. 4.—Shrinkage pattern of a low moisture content piece.

Table 1.—EFFECT OF MOISTURE CONTENT ON TANGENTIAL SHRINKAGE OF WESTERN HEMLOCK DURING KILN-DRYING WITH CONSTANT SURFACE E.M.C. OF 7.5 PER CENT
10 BOARDS

(Expressed in per cent of green dimensions)

	Initial Moisture Content %	Dry Bulb Temperature 120° F. Moisture Content Level 30%	120° F. Moisture Content Level 10%	120° F. Constant Weight	160° F. Moisture Content Level 30%	160° F. Moisture Content Level 10%	160° F. Constant Weight	200° F. Moisture Content Level 30%	200° F. Moisture Content Level 10%	200° F. Constant Weight
High initial moisture content pieces	195	1.0	5.1	5.4	2.4	5.7	5.8	2.2	5.3	5.9
	187	0.8	4.6	5.6	1.7	5.4	5.8	1.3	5.3	5.9
	152	0.8	3.9	4.4	---	---	---	2.4	4.7	5.8
Average		0.9	4.5	5.1	2.0	5.6	5.8	2.0	5.1	5.9
Medium initial moisture content pieces	135	1.4	5.7	6.1	1.5	6.3	6.4	1.4	4.8	5.7
	128	0.6	4.1	4.2	2.6	5.7	6.8	1.9	4.8	5.6
	123	1.0	3.7	3.9	1.3	3.8	4.1	0.9	2.6	4.0
	108	0.9	5.2	5.6	1.8	5.0	5.4	1.4	5.2	-
Average		1.0	4.7	4.9	1.8	5.2	5.7	1.4	4.3	5.1
Low initial moisture content pieces	61	1.1	3.3	3.5	1.8	4.4	4.5	1.2	3.7	4.8
	56	0.5	2.2	2.2	0.3	2.1	2.2	0.5	2.6	3.5
	41	0.4	4.3	4.9	0.6	4.2	4.8	0.7	4.0	4.8
Average		0.7	3.3	3.5	0.9	3.6	3.8	0.8	3.4	4.4

Table 2.—COMPARISON BETWEEN WEIGHT OF WATER PER CUBIC FOOT AND VOLUMETRIC SHRINKAGE

Species	Water per cu. ft.* of wood—lb.	Volumetric Shrinkage* per cent
Douglas fir (mountain)	9	12.1
Sitka spruce	9	11.7
Western red cedar	10	7.8
Average:		10.5
Douglas fir (coast)	12	12.1
Engelmann spruce	13	11.5
Western white pine	14	10.7
Average:		11.4
Western hemlock	18	12.9
Western larch	18	14.0
Ponderosa pine	20	10.5
Average:		12.5

*Forest Products Laboratories of Canada—Mechanical and Physical Properties of Woods Grown in Canada, Sheet E-113.

There are inconsistencies in the above table but the data when plotted show a definite trend and indicate that the amount of water in wood has a bearing on shrinkage of the species listed although not necessarily related to the *percentage* of water present. This trend is similar to that indicated by the dimensional recorder in this study of the shrinkage of western hemlock.

Effect of Specific Gravity on Shrinkage of Western Hemlock

In order to evaluate the effect of specific gravity on the shrinkage of the test pieces, specific gravity sections were cut from each green board, measured, air-dried, and then oven-dried. The sections were then measured in the oven-dry condition and the specific gravity was determined by means of a mercury volumeter. The shrinkage measurements were made by means of a dial micrometer to an accuracy of 1/1000 inch. It has been generally assumed that shrinkage increases with an increase in specific gravity. However, Table 3 shows that although there is a trend towards greater shrinkage with increase in specific gravity, this trend is not as significant in western hemlock as it was at first thought that it might be.

Table 3.—EFFECT OF SPECIFIC GRAVITY TOTAL SHRINKAGE TO OVEN-DRY
Western Hemlock
178 Samples

Specific Gravity Oven-dry Volume Oven-dry Weight	Tangential Shrinkage	Radial Shrinkage
	In Percentage of Green Dimensions	
0.40	6.6	4.6
0.41	8.0	4.4
0.43	7.3	5.0
0.45	8.5	4.8
0.47	7.4	5.3
0.47	9.4	5.6
0.50	9.2	5.8
0.54	8.4	6.0
0.57	5.3	4.4
Av. 0.47	7.8	5.1

Relationship of Radial Shrinkage and Ray Volume

In the course of these investigations on the shrinkage of western hemlock, reports of recent studies by McIntosh[2] and Morschauser[3] on the effects of rays on the shrinkage of red oak was noted. If their hypothesis of ray restraint theory be accepted, it might be assumed that ray volume will have a direct effect on radial shrinkage.

The following (Table 4) shows a number of western softwoods listed in ascending values of radial shrinkage with corresponding ray volumes.

Although there are inconsistencies in the relationship, the general trend, when plotted, indicates that the radial shrinkage increases as the ray volume increases.

[2] McIntosh, D. C. 1954. Some aspects of the influence of rays on the shrinkage of wood. Journal of F.P.R.S. IV (1): 39–42.

[3] Morschauser, C. R. 1954. The effect of rays on the differential shrinkage of wood. Journal of F.P.R.S. IV (5): 280–2.

Table 4.—RELATIONSHIP OF RADIAL SHRINKAGE to RAY VOLUME

	Radial Shrinkage %	Ray Volume*
Western red cedar	2.1	6.9
Western white pine	3.7	6.5
Engelmann spruce	4.2	5.9
Douglas fir (mountain)	4.5	7.3
Ponderosa pine	4.6	6.7
Sitka spruce	4.6	7.2
Douglas fir (coast)	5.0	7.3
Western larch	5.1	10.0
Western hemlock	5.3	8.0

*Brown, H. P., Panshin, A. J., and Forsaith, C. C. 1949. Textbook of wood technology, Vol. 1, McGraw Hill Book Co., New York.

Conclusions

This preliminary study has indicated that western hemlock lumber starts to shrink almost immediately after the commencement of drying. When the temperature and moisture content are both high, the rate of shrinkage is extremely rapid at the beginning of the drying period, but apparently this accelerated shrinkage does not cause an abnormal amount of degrade in the form of excessive checking. Under the above conditions, approximately 25 per cent of the total shrinkage occurs above fiber saturation point.

These measurements of the rate and degree of shrinkage by means of the dimensional recorder indicate that there may be significant relationships between the amount of moisture in, and shrinkage of, western hemlock lumber.

Discussion

L. D. Winkel (Western Pine Assoc.): What was the wet bulb depression in order to make a constant surface equilibrium?

Mr. Fountain: In the high temperature scedule it was 19° F. and in the low temperature schedule it was 22° F.

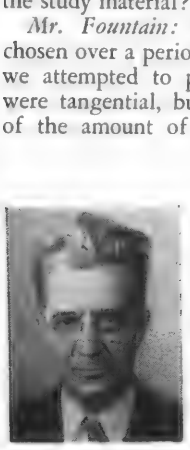
J. D. Snodgrass (Oregon State College): Did compression wood figure in the study material?

Mr. Fountain: The material was chosen over a period of 10 months and we attempted to procure boards that were tangential, but we have no idea of the amount of compression wood that occurred since it is difficult to determine.

S. B. Preston (U. of Michigan): What is the relationship of shrinkage to moisture content?

Mr. Fountain: Shrinkage in hemlock boards occurs considerably before the 30 per cent moisture content level and the rate of shrinkage increases with a rise in temperature. Very wet stock shrinks irregularly when dried quickly at higher temperatures. With high temperature drying, there was less case-hardening and apparently less surface checking than at lower temperatures.

R. C. Rietz (U. S. Forest Products Laboratory): The rate of shrinkage is a function of the amount of moisture loss. In several hardwood studies we have conducted, compression set exists in the core but does not seem to be the case in softwoods.



Swelling of Paint Films in Water

VI. Effects of Different Oil or Oleoresinous Vehicles[1]

F. L. BROWNE

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Discusses the effect of four oil or varnish vehicles on the behavior of free films of paints when soaked in distilled water for three days and then redried. The films were tested when 10 days old and after 15 days of artificial weathering. Measured were changes of density, absorption of water, swelling during absorption, shrinkage on redrying, loss in weight while soaking, and loss in weight while weathering.

THE FIFTH PAPER in this series (3 to 7)[3] described the effect of 44 different pigments on the behavior of free films of single-pigment paints made with linseed oil when the films were soaked in distilled water for 3 days and then redried. The films were tested when 10 days old and also after an additional 15 days of artificial weathering.

This sixth paper describes similar studies of the effects of different oil and oleoresinous vehicles. Unpigmented films of bodied linseed oil, an alkyd-resin vehicle recommended for making house paints, and a phenolic-resin varnish were tested both before and after artificial weathering. The results were compared with previous data for films of unbodied linseed oil. Single-pigment and multiple-pigment paints were made with each of the vehicles, and films with these pigments were tested before and after weathering. The tests included measurements: (1) of changes in density during formation of films, (2) on free films after they were soaked in distilled water for three days, (3) on the redried films, (4) on the absorption of water during soaking, (5) of the swelling in volume, area, and thickness when water was absorbed, (6) of the contraction in volume, area, and thickness when the films were redried, (7) of the loss of soluble matter from the films while they were soaking, and (8) of the loss in weight while the films were artificially weathered.

In the meantime, a number of publications on the swelling of films by other investigators have appeared (1, 9 to 11, 16 to 22).

Vehicles and Paints Tested

Three paint vehicles were chosen: a heat-bodied linseed oil of viscosity Z-6; a commercial long-oil, pure alkyd-resin vehicle sold for use in "stain- and blister-resistant" house paints; and a pure phenolic-resin varnish of 33-gallon length in linseed and tung oils. A fourth vehicle, refined but unbodied linseed oil, had already been tested extensively, as reported in previous papers (4, 7). Driers in the unbodied and bodied linseed oils were lead and manganese naphthenates; in the alkyd-resin vehicle, they were cobalt and calcium naphthenates; and in the phenolic-resin varnish, they were cobalt and lead naphthenates.

Unpigmented films of the alkyd-resin vehicle and the phenolic-resin varnish were tested, and data for unpigmented films of unbodied and bodied linseed oil were available from a previous paper (4).

All experimental paints were made at 30 per cent pigment volume (symbol p/nv 0.30). Each kind of pigment was of the same make and grade in all experimental paints reported in this paper.

With each of the vehicles, there were single-pigment paints made with basic carbonate white lead (symbol L), antimony oxide (symbol A), rutile titanium dioxide (symbol T), zinc oxide (symbol Z), and magnesium silicate (symbol X). There were also three mixed-pigment paints as follows: (a) a lead-zinc paint LZ_{25} (the subscript represents the percentage of the pigment symbolized in the total pigment by volume), (a) an antimony-zinc paint, AZ_{25}, and (c) a titanium-zinc paint, TZ_{25}. In the alkyd-resin vehicle, the titanium-zinc paint also contained magnesium silicate, $TZ_{25}X_{57}$. A fourth mixed-pigment paint, $TA_{25}X_{57}$, was also used with the alkyd-resin vehicle.

The five pigments for the single-pigment paints were chosen on the basis of the absorption and swelling properties previously found for unbodied linseed oil paints (7). Two were chosen for unusually low, one for very high, and two for moderately high absorption and swelling. The mixed-pigment paints represented two combinations of low- and high-swelling pigments and two combinations of moderately high- and high-swelling pigments.

Preparation of Free Films and Tests

Clear vehicles and paints to be tested before weathering were spread on gummed paper by doctor blade and suction plate, and allowed to dry for 10 days. The free films were then stripped from the paper by immersion in cold water for about 15 minutes until the paper backing became wet and the dextrine gum softened. Vehicles and paints to be weathered before testing were spread on tinplate, and

[1] A contributed paper.

[2] Maintained at Madison, Wis. in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to literature cited.

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allowed to dry for 10 days. They were then sprayed with distilled water three times an hour in a Weatherometer for 15 days, and simultaneously exposed to ultraviolet light from a flaming carbon arc enclosed in Corex D glass (1,200 kilowatt-hours of input of electric current). The tinplate specimens were weighed before coating, after the coatings had dried and cured, and after the period of artificial weathering, to determine the loss in weight of the coatings while weathering. Free films were then stripped for testing by amalgamation of the tinplate.

Procedures for measuring absorption, swelling, and solubility were essentially those described previously (4). Test films were cut 1½ by 2½ inches in size, scribed with reference marks for measuring changes in length and width with a traveling microscope, and dried in a desiccator over calcium chloride. The films were then measured for length and width, and weighed in air and under water to determine the initial weight and volume. Each film was submerged in a crystallizing dish under 250 cubic centimeters of distilled water and a weighted pad of glass cloth to prevent undue curling of high-swelling films. The films were soaked for 3 days at 70° F., and weighed under water. They were then sandwiched between microscope cover glasses for measurement of length and width, removed from the cover glasses and quickly blotted with paper towels to remove free water, and weighed in air. Finally, the films were redried for 3 days in a desiccator, and then measured for length and width and weighed in air and under water.

At each of the three test stages, before and after soaking and after redrying, the data yielded the weight in air, W, the volume, V, and the length and width between reference marks. The reasonable assumption that the whole film swelled or shrank in the same proportion as the part between reference marks made it possible to compute the swollen and redried lengths, L, and widths, B, of the entire film from the known initial dimensions. The following relations then apply at each stage of test:

Area	$Q = L \times B$
Thickness	$T = V/Q$
Density	$D = W/V$

Indicating the initial, swollen, and redried stages by the subscripts o, s, and r, respectively, changes in the film usually can be calculated from the relations:

Absorption of water, A, in per cent by volume $= 100\ (W_s - W_r)/V_o$

Increase in volume, $\triangle V_s$, in per cent $= 100\ (V_s - V_r)/V_o$

Increase in area, $\triangle Q_s$, in per cent $= 100\ (Q_s - Q_r)/Q_o$

Increase in thickness, $\triangle T_s$, in per cent $= 100\ (V_s/Q_s - V_o/Q_o)$

Swelling efficiency, in per cent $= 100\ \triangle V_s V_o/A$

Decrease in volume, $\triangle V_r$, in per cent $= 100\ (V_o - V_r)/V_o$

Decrease in area, $\triangle Q_r$, in per cent $= 100\ (Q_o - Q_r)/Q_o$

Decrease in thickness, $\triangle T_r$, in per cent $= 100\ (V_r/Q_r - V_o/Q_o)$

Solubility, S_2, the loss in weight while soaking, in grams per 100 cubic centimeters $= 100\ (W_o - W_r)V_o$

Solubility, S_1, the loss in weight while weathering, is similarly calculated in per cent as 100 times the weight loss divided by V_o.

In the literature on swelling of paint films, the absorption of water has often been reported in percentage by weight for convenience, but the great variation in density of paints impairs even the relative significance of such measurements. Swelling is by nature a volumetric process. There is, therefore, a growing practice of reporting absorption volumetrically (2, 8, 10). Expression of solubility in percentage by weight is similarly questionable. As long as the density of the soluble ingredients remains unknown, the most useful method of reporting solubility for the present purpose seems to be the weight of dissolved matter per 100 cubic centimeters of film.

Occasionally the volume and often the area of a redried film remain greater than they were before soaking, despite loss of soluble substances to the soaking water. If the increase is beyond the limits of experimental error, either there has been a disproportionally large shrinking in thickness or a decrease in film density on redrying after soaking. In such cases, the volumetric swelling was taken as $\triangle V_s = V_s - V_o$ and the areal swelling as $\triangle Q_s = Q_s - Q_o$.

Unweathered Films

The effects of soaking on unweathered films are reported in Table 1.

Density: All four clear vehicles became more dense after they had dried for 10 days. Although the density of the liquid vehicle varied from 0.93 for unbodied linseed oil to 1.02 for the phenolic-resin varnish (nonvolatile only), the 10-day-old films all reached the same density, 1.11. The increase in density was 19.4, 14.4, 11.0, and 8.8 per cent of the density of the liquid unbodied linseed oil, bodied linseed oil, alkyd-resin vehicle, and phenolic-resin varnish, respectively.

The density of all paints made with the four vehicles similarly increased during the 10-day drying period. For paints made with unbodied linseed oil, the percentage increases ranged from 4.7 to 11.3 per cent; for paints made with bodied linseed oil, from 1.3 to 6.5 per cent; for paints made with alkyd-resin vehicle, from 2.9 to 8.6 per cent; and for paints made with phenolic-resin varnish, from 0.8 to 3.2 per cent.

It was shown previously (7) for unbodied linseed oil paints that the increase in density is always less than that calculated on the assumption that the oil in a paint undergoes the same changes in weight, volume, and density that occur in the oil when no pigments are present. Thus pigments alter the course of the drying process in unbodied linseed oil to an extent that varies for different pigments. It now appears that pigments similarly alter the drying of bodied linseed oil, alkyd-resin vehicle, and phenolic-resin varnish. The increase in density during drying was always less than that calculated from the changes in the unpigmented vehicle by an amount that ranged from 0.01 to 0.21. The shortage was usually greatest for white lead, antimony oxide, and zinc oxide, and least for titanium dioxide and magnesium silicate. Also, the shortage was usually greater in bodied linseed oil and phenolic-resin vehicles than in raw linseed oil and alkyd-resin vehicles.

When soaked in water for 3 days, all films, clear or pigmented, decreased in density to an extent roughly proportional to the quantity of water absorbed unless the absorption was less than 1 per cent. Exact proptionality is not to be expected because there was a loss of soluble substances from the films during soaking.

On redrying after soaking, the lost density was regained or exceeded by all films except two—antimony-zinc and titanium-zinc in alkyd-resin vehicle. Higher density after redrying could come from further aging of the paint during the soaking and drying periods, or from loss of soluble ingredients of low density. The two paints that failed to regain their lost density were also the two with the lowest swelling efficiency, which may indicate that they acquired some internal voids from the soaking and redrying treatment.

Absorption of Water: When the clear vehicles were soaked for 3 days, the amount of water they absorbed decreased in the following order: unbodied linseed oil, 21.8 per cent; bodied linseed oil, 9.0 per cent; alkyd resin, 7.7 per cent; phenolic resin, 1.5 per cent. Since the film of alkyd resin was thicker than the others, the absorption by alkyd-resin vehicle may be as great or even somewhat greater than by bodied linseed oil vehicle. If all

absorption by the pigmented films took place in the vehicle, without any effects from the pigments, the absorption should have been 15.3 per cent for all films with unbodied linseed oil, 6.3 per cent for all films with bodied oil, 5.4 per cent for all films with alkyd resin, and 1.0 per cent for all films with phenolic resin. Pigmentation, however, resulted in higher or lower absorptions, according to the nature of the pigments.

To see whether absorption of water by pigments in the absence of vehicle could account for the effects of pigments on absorption by paint films, 3- to 4-gram samples of white lead, zinc oxide, titanium dioxide, and magnesium silicate were each soaked in 150 cubic centimeters of distilled water for 3 days. The water was then decanted and the pigments allowed to dry at room temperature until the weight was constant. The white lead gained 0.044 per cent by weight or 0.3 per cent by volume, zinc oxide gained 0.48 per cent by weight or 2.69 per cent by volume, titanium dioxide gained 0.023 per cent by weight or 0.09 per cent by volume, and magnesium silicate lost 0.18 per cent by weight. Thus the magnesium silicate contained a small proportion of water-soluble matter and the other pigments retained slight amounts of water that was presumably adsorbed. Zinc oxide, as was to be expected, retained more water than white lead or titanium dioxide, but the amount was far too small to account for the large effect of zinc oxide on the absorption of water by paint films.

With paint films of any one pigmentation, the absorption was nearly always highest for the unbodied linseed oil vehicle and lowest for the phenolic-resin vehicle, and was always higher for the alykd-resin vehicle than for the bodied linseed oil vehicle. The differences attributable to kind of vehicle, however, proved less than differences caused by kind of pigment.

Antimony oxide, in all four vehicles, reduced the absorption below th· ab-

Table 1.—DATA FOR FREE, UNWEATHERED FILMS OF DIFFERENT OIL OR VARNISH VEHICLES WITH AND WITHOUT PIGMENTS—CHANGES IN DENSITY; ABSORPTION OF WATER AND SWELLING IN VOLUME, AREA, AND THICKNESS WHEN SOAKED IN WATER FOR 3 DAYS. SWELLING EFFICIENCY; SHRINKING IN VOLUME, AREA, AND THICKNESS WHEN REDRIED; AND LOSS IN WEIGHT BY LEACHING DURING THE SOAKING PERIOD

Vehicle	Density of nonvolatile in liquid paint	Density of film - Dry	Density of film - Swollen in water	Density of film - Redried	Initial thickness of film T_o	Absorption: of water A/V_o	Swelling: In volume ΔQ_s	Swelling: In area $\Delta V_s V_o / A$	Swelling: In thickness ΔT_s	Swelling efficiency	Redried: Volume ΔV_r	Redried: Area ΔQ_r	Redried: Thickness ΔT_r	Loss in weight by leaching $S_o V_o$
					Mils	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Gr. per 100
CLEAR VEHICLES CONTAINING NO PIGMENT														
Linseed oil, not bodied	0.93	1.11	1.09	1.12	3.1	21.8	22.0	9.8	10.8	101	-6.0	-4.9	-1.3	
Linseed oil, heat bodied	.97	1.11	1.09	1.11	3.6	9.0	9.2	6.1	1.4	102	-4.9	-2.6	-2.2	
Alkyd vehicle	1.00	1.11	1.10	1.12	5.6	7.7	8.9	6.0	-.7	116	-4.0	+2.1	-5.7	
Phenolic-resin varnish	1.02	1.11	1.10	1.11	3.9	1.5	1.7	1.0	-.3	113	-1.3	-.1	-1.3	1.3
BASIC CARBONATE WHITE LEAD, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30														
Linseed oil, not bodied	2.70	2.87	2.74	2.90	3.8	8.9	9.3	2.1	5.3	104	-2.5	+.1	-2.1	
Linseed oil, heat bodied	2.71	2.82	2.78	2.87	4.8	3.1	4.2	.8	1.0	135	-2.3	0	-2.5	1.9
Alkyd vehicle	2.79	2.91	2.80	2.98	3.1	9.7	10.0	2.7	3.8	103	-3.3	+.3	-3.5	
Phenolic-resin varnish	2.76	2.80	2.79	2.82	4.8	1.8	2.3	.5	.6	128	-1.2	0	-1.2	
ANTIMONY OXIDE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30														
Linseed oil, not bodied	2.38	2.54	2.52	2.61	3.4	5.3	5.8	2.9	.3	109	-4.3	-1.4	-2.9	4.7
Linseed oil, heat bodied	2.39	2.42	2.42	2.42	5.6	.8	.7	.7	-.5	87	-.7	+.2	-.9	
Alkyd vehicle	2.46	2.57	2.56	2.61	3.3	2.2	2.7	1.8	-.9	123	-2.4	-.7	-1.5	
Phenolic-resin varnish	2.44	2.47	2.48	2.50	5.2	.9	1.2	1.2	-2.0	133	-1.8	+.3	-2.0	1.1
RUTILE TITANIUM DIOXIDE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30														
Linseed oil, not bodied	1.91	2.06	1.80	2.11	3.5	34.9	35.5	17.1	12.4	102	-4.2	+3.3	-7.1	4.1
Linseed oil, heat bodied	1.93	1.99	1.94	2.02	5.2	6.8	7.7	5.7	0	113	-2.2	+.3	-2.1	1.2
Alkyd vehicle	2.05	2.11	1.97	2.15	3.4	16.6	17.2	10.3	3.5	103	-2.9	+.4	-3.2	
Phenolic-resin varnish	1.97	1.99	1.97	2.00	6.6	2.5	3.2	2.5	-.5	128	-1.2	+.4	-1.5	.5
ZINC OXIDE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30														
Linseed oil, not bodied	2.33	2.44	1.80	2.47	3.7	83.3	81.6	28.4	39.2	98	-3.6	+5.0	-8.0	5.7
Linseed oil, heat bodied	2.35	2.45	2.10	2.46	4.3	31.8	31.5	10.9	17.3	99	-1.0	+3.0	-4.0	1.4
Alkyd vehicle	2.41	2.55	1.96	2.58	3.0	61.8	61.5	21.5	29.6	100	-3.6	+6.0	-9.2	6.4
Phenolic-resin varnish	2.39	2.44	2.32	2.45	5.0	9.8	9.9	4.7	4.0	101	-1.5	+1.3	-2.8	1.1
MAGNESIUM SILICATE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30														
Linseed oil, not bodied	1.51	1.68	1.44	1.70	2.9	56.2	56.1	13.7	37.3	100	-3.8	+2.2	-5.8	4.5
Linseed oil, heat bodied	1.53	1.60	1.47	1.62	5.2	28.0	28.5	14.0	10.7	102	-2.1	+1.7	-3.8	1.7
Alkyd vehicle	1.57	1.68	1.49	1.69	3.2	40.3	40.0	16.1	17.6	100	-3.6	+2.8	-6.3	4.1
Phenolic-resin varnish	1.57	1.62	1.54	1.63	5.2	15.3	15.7	7.1	6.2	102	-1.4	+.7	-1.9	.9
LEAD-ZINC, MIXED-PIGMENT PAINTS LZ_{25}, PIGMENT VOLUME 0.30														
Linseed oil, heat bodied	2.63	2.72	2.48	2.74	4.5	16.3	16.5	5.9	9.0	101	-1.0	+.9	-1.8	2
Alkyd vehicle	2.69	2.82	2.06	2.84	3.1	73.5	72.6	26.9	34.4	99	-1.9	+11.5	-12.2	
Phenolic-resin varnish	2.67	2.73	2.67	2.74	4.9	4.5	4.7	2.8	.8	104	-.8	+.4	-1.0	
ANTIMONY-ZINC, MIXED-PIGMENT PAINTS AZ_{25}, PIGMENT VOLUME 0.30														
Linseed oil, heat bodied	2.30	2.45	2.24	2.47	5.3	18.0	18.3	8.8	8.1	102	-1.0	+1.5	-2.5	
Alkyd vehicle	2.44	2.57	1.96	2.53	3.1	64.2	62.3	34.0	21.2	97	0	+13.4	-11.5	
Phenolic-resin varnish	2.44	2.46	2.38	2.48	5.0	7.3	7.5	4.6	1.4	103	-1.3	+.7	-2.2	
TITANIUM-ZINC, MIXED-PIGMENT PAINTS TZ_{25}, PIGMENT VOLUME 0.30														
Linseed oil, heat bodied	2.04	2.11	1.90	2.12	4.8	23.3	23.5	11.0	10.1	101	-1.1	+2.4	-3.3	
Alkyd vehicle[1]	1.85	1.97	1.52	1.95	3.3	86.4	84.0	36.4	33.0	97	-2.5	+15.2	-15.3	
Phenolic-resin varnish	2.09	2.11	2.05	2.13	5.2	6.4	6.5	5.9	-.8	102	-1.6	+1.6	-3.3	
TITANIUM-ANTIMONY-MAGNESIUM SILICATE PAINT $TA_{25}X_{57}$, PIGMENT VOLUME 0.30														
Alkyd vehicle	1.86	2.02	1.84	2.04	3.0	22.8	23.4	8.1	11.5	103	-3.0	+.8	-3.6	

[1] The pigment in this paint contained titanium dioxide, zinc oxide, and magnesium silicate; paint $TZ_{25}X_{57}$, p/nv 0.30.

sorption to be expected if the vehicle absorbed proportionately as much water as it did without pigment. Thus in unbodied oil, where 15.3 per cent absorption might be expected, the antimony oxide paint absorbed only 5.3 per cent. Basic carbonate white lead likewise reduced the absorption in unbodied and bodied linseed oil, but failed to reduce or perhaps slightly increased the absorption in alkyd-resin and phenolic-resin vehicles, although the absorption still remained relatively low.

All other pigments greatly increased the absorption of water above that expected for the proportion of clear vehicle in the paint. Among the single-pigment paints, zinc oxide and magnesium silicate caused the highest absorptions. Zinc oxide was highest in unbodied and bodied linseed oil and in alkyd resin, but magnesium silicate exceeded zinc oxide in phenolic-resin vehicle. In zinc oxide, the absorption reached 83.3 per cent in unbodied linseed oil and 61.8 per cent in alkyd-resin vehicle. Magnesium silicate in phenolic-resin vehicle absorbed 15.3 per cent. Absorptions by titanium dioxide paints were 34.9, 6.8, 16.6, and 2.5 per cent in unbodied oil, bodied oil, alkyd resin, and phenolic resin, respectively.

Absorptions by mixed-pigment paints, all of which contained at least one high-swelling pigment, were relatively high. Presence of a low-swelling pigment in the mixture moderated the absorption appreciably in bodied linseed oil or phenolic-resin vehicle, as was previously found in unbodied linseed oil (4), but in alkyd-resin vehicle, mixtures of low- and high-swelling pigments usually showed higher absorption than the zinc oxide alkyd-resin paint. Apparently, high-swelling pigments tend to dominate low-swelling pigments in all vehicles.

Swelling: The volumetric swelling of films was usually equal to or a trifle greater than the volume of absorbed water. The swelling efficiency was therefore usually 100 per cent or a little over, which means that each cubic centimeter of water absorbed increased the volume of the film by a like amount or a little more. The slight excess of swelling over absorption may be due to the experimental difficulty of weighing the soaked films in air without significant loss of absorbed water by evaporation. If some films really did swell by more than the volume of water absorbed, it may be that the films, after their initial formation and hardening (1, 14), acquired internal compression stresses from further absorption of oxygen, and that the stresses were released to add an increment of volume as soon as absorbed water plasticized and softened the films. The data show no evidence of the compression of swelling liquid reported by Weinmann (22). A swelling efficiency greater than 104 per cent appears in Table 1 only when the absorption was less than 8 per cent and the excess of swelling over absorption less than 1.3 percent; that is, when the measured values were small enough to make the experimental errors relatively large. Nevertheless, the relatively large swelling efficiency of the clear film of alkyd-resin vehicle, for example, appeared again when the corresponding weathered film was tested. Similarly, a swelling efficiency of less than 97 per cent was recorded only for antimony oxide in bodied oil, for which the absorption was only 0.8 and the volumetric swelling 0.7 per cent. The two measurements of 97 per cent swelling efficiency, however, may be accepted as true deficiency in swelling because the film density was less after redrying than before soaking, which indicates that soaking developed void spaces capable of holding free water, the evaporation of which caused no shrinking of the swollen films.

All films swelled in area when soaked in water, but areal swelling was not proportional, in general, to volumetric swelling. Usually, areal swelling was much less than volumetric swelling, but sometimes the two were nearly or even fully equal, especially when the absorption was relatively low. Of course, when areal swelling was large in relation to volumetric swelling, swelling in thickness was correspondingly small, and for seven of the films it was even negative. That is, the films became thinner on swelling.

It was shown previously (3, 7) that the ratio of length to width in areal swelling of linseed oil paints may vary greatly among paints of different pigmentation, and may vary greatly for any one paint according to the tool used and methods followed in application, particularly if the paint contains acicular pigments that may become preferentially oriented when the paint is spread and dried. Similar variations were observed among paints in the vehicles of the present study, but these variations need not be presented in detail. It is sufficient to point out that volumetric swelling is independent of a number of considerations that markedly affect the distribution of swelling among length, width, and thickness (11). Volumetric swelling is therefore more readily reproducible and, in general, more reliable than areal or linear swelling.

Shrinkage on Redrying: On redrying, all swollen films shrank to a volume less than that before soaking, except the film of antimony-zinc paint in alkyd resin, which shrank only to its volume before soaking. Such loss in volume is due primarily to loss of soluble substances during soaking. Since the nature, and therefore the density, of the dissolved substances has not yet been determined, it is not possible to compare the volume lost by the film with that of the substances dissolved.

However, another factor must also be considered, namely, the change in density of the film before soaking and after redrying due to aging of the film or to development of voids within the film. The antimony-zinc paint in alkyd resin, which had the same volume after redrying as before soaking, despite a solubility of 3.3 per cent, exhibited such formation of voids by decreased density and low swelling efficiency. Similarly, titanium-zinc paint in alkyd resin, which showed a loss in density and low swelling efficiency, experienced only 2.5 per cent loss in volume despite 7.3 per cent solubility.

After redrying, 27 of the 34 films remained larger in area than they were before soaking, 2 were unchanged in area, and 5 decreased in area. Of course, failure to shrink in area when the volume shrank caused correspondingly large shrinkage in thickness. All seven films that were no larger in area after redrying than before soaking were either clear films or films pigmented only with white lead or with antimony oxide. When high-swelling pigments were present, the redried area was always greater than the presoaked area.

Loss in Weight While Soaking: If allowance is made for the differences in film thickness, the solubilities of the films of clear unbodied and bodied linseed oil and alkyd-resin vehicle may be considered about equal at 5.8 grams per 100 cubic centimeters for 3.7-mil thickness. The phenolic-resin varnish was much less soluble, 1.3 grams per 100 cubic centimeters. For the 70 per cent by volume of vehicle in the pigmented films, the solubility, if the pigments had no effect, should be 4.1 grams per 100 cubic centimeters for the first 3 vehicles and 0.9 gram per 100 cubic centimeters for the phenolic-resin varnish.

In unbodied linseed oil, the solubilities for paints with pigments other than zinc oxide were not far from 4.1 grams per 100 cubic centimeters, but zinc oxide raised the solubility to 5.9 grams per 100 cubic centimeters. In bodied linseed oil, no paint was higher than 1.9 grams per 100 cubic centimeters in solubility. In alkyd resin, the solubility of all paints was more than 1.9 grams per 100 cubic centimeters, but only the zinc oxide and the titanium-zinc paints were much more soluble than 4.1 grams per 100 cubic

centimeters. In phenolic resin, no paint reached 1.9 grams per 100 cubic centimeters in solubility, and only the zinc oxide, titanium-zinc, antimony-zinc, and antimony oxide paints exceeded the solubility expected of the clear vehicle, 0.9 gram per 100 cubic centimeters.

There seems to be a rough relation between the effect of pigments on the solubility of paint films and on film absorptions and swelling (7). Meier and Schulz (16) found that removal of water-soluble ingredients from pigments reduces the swelling of paints made with them, but that paints with some pigments, particularly zinc oxide, still swell more than the clear vehicle, even if the pigments have been thoroughly leached. It may well be that pigments affect film swelling at least in part by altering the formation of water-soluble substances formed from the vehicles during oxidation, aging, or hydrolysis (1, 15).

Weathered Films

Table 2 gives the effects of weathering on oil-type paints that were weathered artificially for 15 days (1,200 kilowatt-hours of electric input), and the subsequent effects of soaking on these artificially weathered films.

Loss in Weight While Weathering: All films lost weight during the 15-day period of artificial weathering, as other workers have found (1, 13). Among the clear vehicles, the losses per 100 cubic centimeters were 28.1 grams for unbodied linseed oil, 12.7 grams for bodied linseed oil, 6.1 grams for alkyd-resin vehicle, and 2.3 grams for phenolic-resin varnish. For the proportion of vehicle in the pigmented films, the losses would be 19.7, 8.9, 4.3, and 1.6 grams per 100 cubic centimeters, respectively, if the pigments exerted no effect.

In unbodied linseed oil vehicle, all pigments except zinc oxide made films that lost more than 19.7 grams in weight while weathering. Zinc oxide decreased the loss materially. In bodied oil vehicle, on the other hand, all pigments except magnesium silicate reduced the loss to less than 8.9 grams. Zinc oxide or any pigment mixture that included zinc oxide was particularly effective in reducing this weight loss. Magnesium silicate increased the loss slightly. In alkyd-resin vehicle, pigments usually increased the weight loss to more than 4.3 grams, but zinc oxide and mixtures containing zinc oxide gave only slight increases or even slight decreases in the weight loss. In phenolic-resin varnish, pigments usually increased the weight loss, and zinc oxide increased it as much or more than other pigments.

Since water extracts appreciable quantities of zinc oxide from films of linseed oil paints, but extracts little or none of the other pigments used in these tests (3, 7, 12), it might be expected that the loss of weight on weathering would be higher for the paints that contain zinc. The fact that zinc oxide tends instead to reduce the weathering loss indicates that the effect of zinc on the solubilization of the vehicle is more important than the reaction of zinc with acid decomposition products of the vehicle to form soluble soaps (1, 15).

Density: All films were higher in density after the weathering period than they had been when dried for 10 days but not yet weathered. The increase was due to further contraction in volume on aging and weathering and to loss of vehicle constituents that are much less dense than the pigments.

When clear films of the four vehicles were weathered, the density increased 5.4, 4.5, 3.6, and 4.5 per cent for unbodied oil, bodied oil, alkyd vehicle, and phenolic-resin varnish, respectively. For the films of unbodied oil paints, the density increase was 7.8 to 15.7 per cent, and was always greater than that for the clear oil without pigment. For the films of pigmented phenolic-resin varnish, on the other hand, the density increase was only 2.5 to 3.5 per cent, and was always less than that for the clear varnish. For the films of bodied oil paints and alkyd-resin paints, except those containing zinc oxide, the density increase always exceeded that of the clear vehicle. The increase was 6.0 to 7.5 per cent for bodied oil paints, and 4.2 to 7.8 per cent for alkyd-resin paints. When the paint contained zinc oxide, the density increase was always less than that for films containing any other pigment in the same vehicle.

In general, pigments exerted an effect on density increase during weathering that was opposite to their effect during film formation and drying. Pigmentation delayed the density increase during drying of the liquid paint, but when the pigmented films were weathered, they tended to catch up with the increase in density of the clear vehicles. A comparison of the density of the weathered films with the density of 10-day-old films calculated on the assumption that pigments do not alter the behavior of the vehicle shows that weathered films of unbodied oil paints reached a density 2 to 12 per cent greater than theoretical for 10-day-old films, weathered bodied oil or alkyd-resin paints came within 2 per cent above or below theoretical, and phenolic-varnish paints failed to reach theoretical by 1 to 4 per cent.

When the weathered films were soaked in water for 3 days, the density decreased roughly in proportion to the quantity of water absorbed, unless the absorption was less than 2.5 per cent. After redrying, the density returned to its value before soaking, or slightly higher, for all but seven films, six of which became somewhat porous, as indicated by their lower swelling efficiency and larger volume after redrying.

Absorption of Water: Weathering had little effect on the absorption of water by clear films of unbodied linseed oil and of phenolic-resin varnish. It diminished the absorption by clear films of alkyd-resin vehicle only slightly, and greatly increased the absorption by clear films of bodied linseed oil so much that the bodied oil films absorbed more water after weathering than the unbodied oil films did before they were weathered.

Pigmented films that absorbed more than 9.0 per cent of water before weathering always absorbed less water after they were weathered. They absorbed much less if their absorption before weathering exceeded 20 per cent. Weathering also diminished the absorption of most pigmented films that absorbed less than 9.0 per cent before weathering. The exceptions were white lead in unbodied and bodied oils, antimony oxide in bodied oil, alkyd resin, and phenolic resin, and lead-zinc in phenolic resin. For these exceptions, weathering increased the absorption slightly or failed to decrease it.

In weathered films of unbodied linseed oil, the only pigment that caused absorption as great or greater than that to be expected of the proportion of clear vehicle in the film was zinc oxide. In weathered films of bodied oil, clear films were so much more absorptive after weathering than before that all pigments reduced the absorption below that expected of the proportion of vehicle in the films. In weathered films of alkyd resin or phenolic resin, however, the absorption was as great or greater than that expected of the proportion of vehicle in the films, except with antimony oxide, with which the absorption was slightly less.

Swelling: For nearly half of the weathered films, the volumetric swelling was less than the absorption of water, and the swelling efficiency was therefore less than 100 per cent. That was the case with all unbodied oil paints, although the unbodied oil without pigments had 100 per cent swelling efficiency. The tendency for weathering to reduce swelling efficiency has been observed repeatedly in previous work, and is attributed to the development of voids within the film that are capable of holding free water that causes no swelling.

Weathered films of bodied oil were the only unpigmented films to have less than 100 per cent swelling efficiency. Bodied oil paints that contained white lead had only 75 per cent swelling efficiency, and the zinc oxide and lead-zinc paints had a 99 per cent efficiency. Bodied oil paints with antimony oxide, titanium dioxide, or magnesium silicate had at least a 100 per cent swelling efficiency. Weathered films of unpigmented alkyd resin, like the corresponding unweathered films, swelled beyond the volume of water absorbed, which may indicate a release of internal stresses acquired when the films originally dried. If such a release did occur, these internal stresses were absent or less significant in the films of weathered alkyd-resin paints, none of which had much more than 100 per cent swelling efficiency, and three of which had less than 100 per cent efficiency. Weathered films of phenolic-resin varnish, with or without pigments, were too low in absorption and swelling to permit reliable deductions from the variations in swelling efficiency.

The swelling in area and thickness of weathered films exhibited much the same variations from proportionality to volumetric swelling that have already been discussed for unweathered films.

Shrinkage on Redrying: On redrying after soaking, all but one of the weathered films shrank to a volume closer to that of the film before soaking than was the case with the unweathered films. For the one exception, the redried volume was within 0.7 per cent of the initial volume for both unweathered and weathered films. As a rule, the redried volume was less than the volume before soaking, but for weathered films of six paints, the redried volume slightly exceeded the initial volume. The smaller residual shrinkage of weathered films may be attributed to less solubility during soaking, and perhaps to less swelling during the soaking period.

On redrying, weathered films, like the unweathered films, tended to

Table 2.—DATA FOR FREE, WEATHERED FILMS OF DIFFERENT OIL OR VARNISH VEHICLES WITH AND WITHOUT PIGMENTS—CHANGES IN DENSITY; ABSORPTION OF WATER AND SWELLING IN VOLUME, AREA, AND THICKNESS WHEN SOAKED IN WATER FOR 3 DAYS. SWELLING EFFICIENCY; SHRINKING IN VOLUME, AREA, AND THICKNESS WHEN REDRIED; AND LOSS IN WEIGHT BY LEACHING DURING THE SOAKING PERIOD

Vehicle	Weight loss while weathering S_1/V_0	Density of film: Dry	Density of film: Swollen in water	Density of film: Redried	Initial thickness of film T_0	Absorption of water A/V_0	Swelling: In volume ΔV_s	Swelling: In area ΔQ_s	Swelling: In thickness ΔT_s	Swelling efficiency $\frac{\Delta V_s V_0}{A}$	Redried: Volume ΔV_r	Redried: Area ΔQ_r	Redried: Thickness ΔT_r	Loss in soaking: weight S_2/V_0
	Percent				Mils	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Gr. per 100 cc.
CLEAR VEHICLES CONTAINING NO PIGMENT														
Linseed oil, not bodied	28.1	1.17	1.14	1.17	3.7	20.4	20.5	4.4	15.5	100	-2.2	-1.7	+0.3	2.9
Linseed oil, heat bodied	12.7	1.16	1.13	1.19	4.1	28.1	27.5	10.1	14.9	98	-.7	+2.1	+.2	1.8
Alkyd vehicle	6.1	1.15	1.15	1.15	5.1	4.8	5.5	3.5	1.0	114	-1.4	-.3	-1.2	.5
Phenolic-resin varnish	2.3	1.16	1.16	1.14	3.9	1.5	2.0	1.0	0	133	-1.0	-.2	-1.0	.5
BASIC CARBONATE WHITE LEAD, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30														
Linseed oil, not bodied	21.0	3.26	3.06	3.11	2.8	9.9	8.7	.7	8.8	88	+2.3	-.7	+2.1	2.9
Linseed oil, heat bodied	7.6	2.99	2.92	2.96	4.0	4.8	3.6	1.0	3.2	75	+.4	-.6	+1.0	2.0
Alkyd vehicle	4.9	3.05	2.98	3.06	2.9	4.2	4.3	1.4	2.7	102	-.8	-.8	0	1.6
Phenolic-resin varnish	2.3	2.87	2.85	2.88	4.7	1.5	1.5	0	.9	100	-.7	-.5	-.2	1.1
ANTIMONY OXIDE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30														
Linseed oil, not bodied	34.4	2.94	2.97	2.97	2.9	2.5	2.3	2.3	-.7	92	-1.5	-.8	-.3	1.5
Linseed oil, heat bodied	5.3	2.60	2.58	2.61	4.8	1.5	1.5	1.3	-1.0	100	-.6	-.2	-.8	1.0
Alkyd vehicle	11.0	2.77	2.74	2.77	3.1	2.4	2.2	2.1	1.0	92	-.4	-1.0	+.7	.3
Phenolic-resin varnish	2.9	2.54	2.54	2.55	4.8	.9	.7	.9	0	76	-.7	-.9	+.6	.9
RUTILE TITANIUM DIOXIDE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30														
Linseed oil, not bodied	24.1	2.34	2.32	2.37	3.1	8.3	5.7	3.6	1.9	69	-1.8	-1.3	0	1.0
Linseed oil, heat bodied	7.3	2.14	2.10	2.14	4.2	3.9	3.9	3.9	1.0	100	-.5	-1.1	+1.0	.8
Alkyd vehicle	7.4	2.22	2.18	2.23	3.2	3.4	3.1	2.9	1.3	91	-.4	-1.3	+1.3	.4
Phenolic-resin varnish	1.4	2.06	2.04	2.07	4.5	1.9	2.0	1.6	-.4	110	-.7	0	-.9	.3
ZINC OXIDE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30														
Linseed oil, not bodied	11.7	2.63	2.30	2.61	3.8	28.2	26.0	7.4	26.0	92	0	+1.4	-.3	.8
Linseed oil, heat bodied	3.3	2.55	2.36	2.55	4.3	14.2	14.0	3.6	10.3	99	+.1	-.1	0	.3
Alkyd vehicle	6.3	2.63	2.40	2.62	2.8	17.8	16.8	4.4	11.9	94	+.3	+.3	0	.5
Phenolic-resin varnish	3.6	2.52	2.45	2.53	4.3	5.3	5.5	1.3	3.7	104	-.7	-.4	-.5	.6
MAGNESIUM SILICATE, SINGLE-PIGMENT PAINTS, PIGMENT VOLUME 0.30														
Linseed oil, not bodied	28.4	1.89	1.81	1.89	2.4	9.9	9.8	5.0	6.7	99	-2.1	-3.4	+.1	3.4
Linseed oil, heat bodied	10.5	1.71	1.61	1.72	4.8	14.9	15.3	6.8	7.3	102	-1.0	+1.0	-2.1	.6
Alkyd vehicle	11.4	1.75	1.69	1.78	3.2	12.1	12.2	4.3	5.4	101	-2.2	+.5	-2.5	.9
Phenolic-resin varnish	2.3	1.66	1.61	1.67	5.1	8.9	9.4	2.0	6.2	105	-.9	-.1	-1.2	.3
LEAD-ZINC, MIXED-PIGMENT PAINTS LZ_{55}, PIGMENT VOLUME 0.30														
Linseed oil, heat bodied	1.6	2.82	2.58	2.82	4.5	15.7	15.3	4.6	9.9	98	-.3	+.9	-1.1	.9
Alkyd vehicle	4.8	2.92	2.60	2.93	3.0	20.3	20.2	5.1	13.6	99	-.9	+1.5	-2.3	1.2
Phenolic-resin varnish	2.2	2.76	2.69	2.78	4.6	5.4	5.4	2.1	2.4	100	-1.2	-.2	-1.3	1.4
ANTIMONY-ZINC, MIXED-PIGMENT PAINTS AZ_{25}, PIGMENT VOLUME 0.30														
Linseed oil, heat bodied	1.8	2.55	2.35	2.53	5.0	14.7	14.0	5.6	8.6	95	+.2	-.9	+1.0	1.0
Alkyd vehicle	3.9	2.64	2.37	2.65	2.9	20.2	20.3	9.3	9.3	100	-.7	+3.3	-3.8	.5
Phenolic-resin varnish	3.7	2.54	2.47	2.55	4.6	4.2	4.5	1.6	2.4	107	-.7	-.4	-.7	.7
TITANIUM-ZINC, MIXED-PIGMENT PAINTS TZ_{25}, PIGMENT VOLUME 0.30														
Linseed oil, heat bodied	1.2	2.19	2.02	2.17	4.6	16.1	15.9	6.5	8.7	99	+.7	+1.2	-.7	.5
Alkyd vehicle[1]	3.1	2.02	1.85	2.02	3.2	20.2	20.1	6.9	12.0	100	-.6	+3.2	-3.8	.7
Phenolic-resin varnish	2.3	2.16	2.12	2.17	4.7	4.3	4.8	2.0	1.9	111	-.8	-.3	-.8	.3
TITANIUM-ANTIMONY-MAGNESIUM SILICATE PAINT $TA_{25}X_{57}$, PIGMENT VOLUME 0.30														
Alkyd vehicle	7.6	2.07	2.04	2.10	3.1	4.8	4.8	2.2	2.0	100	-1.5	-.9	-.7	.8

[1] The pigment in this paint contained titanium dioxide, zinc oxide, and magnesium silicate; paint $TZ_{25}X_{57}$ p/nv 0.30.

shrink less in area and more in thickness, rather than in proportion to the volumetric shrinkage. The discrepancy generally was less for the weathered than for the unweathered films, however. Thus only 10 of 34 weathered films remained larger in area after redrying than before soaking, compared to 27 of the 37 unweathered paint films. Weathered paint seems to be less able to readjust the ratios among length, width, and thickness during changes in volume than is unweathered paint.

Loss in Weight While Soaking: The solubility of most weathered films during soaking was less, usually much less, than that of the corresponding films before weathering. Exceptions were four bodied linseed oil paints and two phenolic-resin paints, among which the solubility of the weathered film exceeded that of the unweathered film by more than 0.2 grams per 100 cubic centimeters only when the solubility of the weathered film was no greater than 1.4 grams per 100 cubic centimeters.

Among the weathered films, the solubility was always higher for unbodied linseed oil films than for the corresponding films with any other vehicle. Bodied linseed oil films stood second in solubility unless they contained zinc oxide, in which case the corresponding alkyd-resin films usually were more soluble than the bodied oil films. The solubility of weathered phenolic-resin films was less than 1.0 gram per 100 cubic centimeters except when the pigment was white lead or lead-zinc, for which the solubilities were 1.1 and 1.4 grams per 100 cubic centimeters, respectively.

Conclusions

The formation and hardening of films results in increased density, and the density increases still further when the films are weathered. Ten-day films of all four of the clear vehicles had densities of 1.11. After weathering artificially for 15 days, the densities ranged between 1.15 and 1.17, although the densities of the liquids before spreading varied from 0.93 to 1.02.

When pigments are incorporated in the vehicles, the density increase during formation and hardening of films is diminished. The increase in density during drying is always less than that calculated on the assumption that the vehicle in paint undergoes the same changes in weight, volume, and density as the clear vehicle without pigment.

Pigments alter the course of drying of bodied oil and of phenolic-resin vehicles relatively more seriously than they do that of unbodied oil and alkyd-resin vehicles. White lead, antimony oxide, and zinc oxide exert more effect than titanium dioxide and magnesium silicate. During weathering, however, pigments have an opposite effect because the density increase of pigmented films tends to catch up with that of the corresponding clear vehicle.

The four dissimilar vehicles resemble one another in that their films absorb water, swell, and lose soluble matter when soaked in distilled water for 3 days and, on redrying, shrink to a volume usually smaller than that before soaking. The changes are usually much the greatest in magnitude for unbodied linseed oil (21.8 per cent absorption), least for phenolic-resin varnish (1.5 per cent absorption), and about the same intermediate magnitude for bodied linseed oil and alkyd-resin vehicle. Weathering leaves the changes nearly as great for unbodied oil and for phenolic-resin varnish, reduces them slightly for alkyd-resin, but increases them for bodied oil to as much or more than those for unbodied oil.

Pigmentation greatly alters the absorption of water by films of all four vehicles. Even the low-absorbing phenolic-resin varnish, which absorbs only 1.5 per cent when the film contains no pigment, absorbs 15.3 per cent when pigmented with magnesium silicate. Absorptions greater than 83 per cent in unbodied oil films, 31 per cent in bodied oil films, and 86 per cent in alkyd-resin films can occur with some pigments. Although weathering materially decreases the absorption by pigmented films, it may remain well above that of the vehicle without pigment.

Among the pigments, zinc oxide, magnesium silicate, and titanium dioxide increase absorption in all vehicles, but antimony oxide and white lead reduce absorption or at least fail to increase it very much. In mixture, high-absorptive pigments dominate over low-absorptive pigments.

Unweathered films, either without pigments or pigmented at 30 per cent pigment volume, usually swelled in volume by the volume of water absorbed; that is, their swelling efficiency is 100 per cent within the experimental error. There are perhaps rare cases of more than 100 per cent swelling efficiency that may be attributed to internal compression stresses from absorption of oxygen after initial formation and hardening of a film. Release of these stresses adds slightly to volume as soon as absorbed water plasticizes and softens the film.

Swelling efficiency less than 100 per cent, which is sometimes exhibited by unweathered films containing zinc oxide and more generally in weathered films, is attributed to development of porosity when soluble material is leached from the film. When redried, however, the film fails to shrink enough to close the voids.

Volumetric swelling is distributed anisotropically and not very reproducibly between area and thickness of both pigmented and unpigmented films, both before and after weathering.

When the films are redried after soaking, nearly all unweathered films and most weathered films shrink to less than the volume before soaking because of loss of soluble material during soaking. Similarly, the density of the wet film decreases in proportion to the water absorbed. When the film is redried the density usually exceeds the density before soaking, because the soluble materials lost are relatively light in weight. Failure of a redried film to shrink to its volume or less than its volume before soaking, which is usually coupled with failure of the redried density to exceed the density before soaking, is taken as an indication of development of porosity within the film.

All films lose weight while weathering. The unpigmented films of the 4 vehicles lose weight in the decreasing order, unbodied oil, bodied oil, alkyd-resin, phenolic-resin. Pigments usually tend to increase the weight loss by unbodied oil, alkyd-resin, and phenolic-resin films, but they tend to decrease the loss by bodied oil paints films. Zinc oxide, however, reduces the weight loss or fails to increase it as much as other pigments in all vehicles except phenolic-resin, in which zinc oxide causes greater loss than other pigments.

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U. S. Navy Experience with Carbides Applied to Woodworking Machines[1]

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The Bureau of Ships has conducted training with carbide tools since 1941. Applications of carbide cutting tools in shipbuilding are described and their advantages illustrated. Training films of actual operations were made in shipyards and aboard an aircraft carrier.

THE BUREAU OF SHIPS in 1941 recognized the need for a carbide training program for machine tool applications. We were required to machine new and tougher materials and harder metals. This called for more horsepower, higher speeds, and more feeds on the machine tools. World War II was coming up on the horizon and the emergency seemed to be pressing continually for more production each day.

It was at this point that the Bureau decided to organize a training program for instruction in the handling, grinding, and proper application of carbides. The program was designed for the education of mechanics in the machine shops of all the Naval Shipyards. We had had some experience with carbide tools as far back as 1936, but from that time through 1941, the applications were few and carbide knowledge was limited. The Carboloy Company of Detroit, Michigan, was contacted and through this company the training program with carbide tools got underway.

Several people were selected from each of the 11 Naval Shipyards, and they were sent to Detroit for a complete training course in carbide tooling. They were then sent to the University of Michigan for a few weeks for additional training and finally to various industrial manufacturers where they were able to witness practical applications of high production carbide tools. Of course, carbides were comparatively new even to industry at this time. A few selected plants known to have progressed more rapidly than others were contacted for further technical assistance.

A progressive carbide training program for machine tools has been continually maintained. We are constantly endeavoring to keep abreast of industry and while we are never completely satisfied, we feel that much progress has been accomplished.

Comprehensive Training Program

In 1949 a comprehensive training program introducing carbides to our woodworking shops was started. A training program was organized and set up in three phases. In the first phase, personnel from each shipyard carefully selected for their ability to instruct others were taken on a conducted tour of industry and shown some of the high production applications of woodworking machinery using carbides in an endeavor to "sell" them on the justification for carbides. They were then taken to the Redco Company in Red Line, Pa., where they were instructed in the application of carbides to various cutting heads, saws, and other cutting tools. They saw how the tools were made, ground, and used.

The second phase covered production of a training film. It was believed that in order to get the important technical information across to the people at the shipyard level and to show some of the best methods and applications, this could best be accomplished through the medium of a training film. With

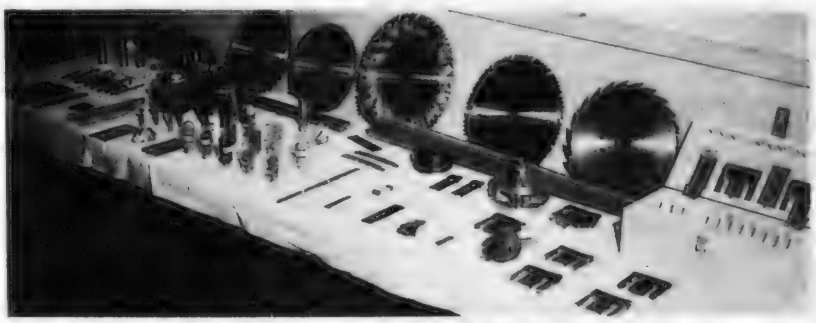

Fig. 1.—Display of carbide woodworking tools used during seminars at Naval Shipyards.

[1] Presented at Session X, Machining, FPRS Ninth National Meeting, June 21–24, 1955, in Seattle, Wash.

The Author: T. M. Kelley studied engineering at U. of Virginia, was employed by Seaboard Airline Railroad, Ford Motor Co., and Newport News Shipbuilding and Drydock Corp. before joining Navy Department. He has been mechanical engineer with the Bureau of Ships for 13 years, including 5 years as project engineer on research and development of machine tools and woodworking machinery.

the use of the training film and competent technicians accompanying the film, a personal showing at all of the shipyards permitted a great deal to be accomplished. An excellent opportunity was afforded for us to impart "know-how" and experience to many hundreds of our journeymen.

The third phase was an advanced training seminar. A skilled technical team visited all of the shipyards. It was composed of engineers from government and industry. The team gave lectures, demonstrations, displayed many samples of carbides and tools, and showed the Navy training films on carbide for woodworking machines.

During this training program, we machined hardwoods, laminates, plastics, phenolics, impregnated woods, hard rubber, and other abrasive materials. Another of the problem materials machined in our shipyards is teak. This is used for decking on battleships, cruisers, some aircraft carriers, and auxiliary ships. Teak has long been regarded as the ideal wood for the decking of these vessels but it is a scarce and costly material and is highly abrasive because of the fine sand or silicon content within the pores of the wood. It costs us approximately $1.50 a board foot finished. High speed steel will not stand up very long when used for machining teak. For example, on one batch of teak at one of our yards, high speed steel would not successfully machine as much as 200 lineal feet of the material. With cemented carbides, we machined as high as 150,000 lineal feet of the same material without regrinding.

Another very tough material that presents a problem in our yards is "ABK" phenolic. It is used for stern tube bearings for our large vessels. At one time, we machined this material in the machine shop on milling machines. These bearing staves have to be machined with angles on the sides and a convex on the outside of the periphery to form a circular ring sector. Approximately 60 of these pieces are assembled together, thus forming the bearings in the stern tubes. Previously, it required approximately one hour to machine one of these staves with high speed steel. Today, with tungsten carbide knives mounted in the forehead molder, we can machine this material cutting all four sides in one operation at approximately 50 feet per minute. This is an increase in production of approximately from 3 feet an hour to 50 feet per minute.

We expect our woodwork shops to produce anywhere from 50 to 1,000 to one between down times using carbides as compared with high speed steel. In machine shops using carbides, we normally expect from one to six times that of high speed steel, and in rare cases, have reached as high as 35 to 1.

In some Naval establishments, we use hard rubber up to 2 and 3 inches thick for many purposes including decking in submarines. We use wax cast in clay molds in solid blocks up to 1½ tons for ship design models to be tested in tanks and we also make models of laminated wood. These materials on the surface may not seem to present much of a machining problem, but actually high speed steel will not stand up very long on either of these materials because of the highly abrasive ingredients contained in them.

We also machine many other materials such as non-ferrous metals on woodworking machines; we have used shapers with 8-inch cutterheads, turning approximately 7,000 RPM, using CO_2 as a coolant, and an oil mist as a lubricant. When using CO_2 as a coolant, and a mist of oil as a lubricant, you can machine material such as aluminum and some brass at fantastic speeds and feeds with low micro finishes.

During our seminar at the shipyards, we taught our people what carbides are, how they are made, how to handle them, grind them and use them, and their economics. We showed samples of pure tungsten, tungsten carbide, tantalum, tantalum carbide, columbium, columbium carbide, titanium carbide, titanium, and various other materials such as carbon or lamp black, cobalt, and scheelite, all of which are used in the manufacture of various grades of carbide tools. We also demonstrated some of the new ceramics and carbides that we have received from various foreign countries for testing purposes, some of which are most interesting.

Wood Used in Shipbuilding

In this atomic age with jet engines, supersonic speeds, and travel, we look on the United States Navy, the largest in the world, as being a navy with ships of all steel. Most of you will be surprised to find out just how much wood we do use. For instance, we have one shipbuilding program going on at the present time which requires 30 million board feet of white oak and this is not the principal wood used by the Navy. White oak ranks second in quantity among the woods used with Douglas-fir the leader; some of the softwoods used in large quantities by the Navy are southern white cedar, orford cedar, Alaska and western red cedar, cypress, hemlock, tamarack, white pine, sugar pine, ponderosa, red and lodgepole pine, redwood, and spruce. Some of the hardwoods are white oak, ash, basswood, beech, birch, cherry, gum, elm, hickory, iron bark, lignum vitae, mahogany, maple, teak, and yellow poplar.

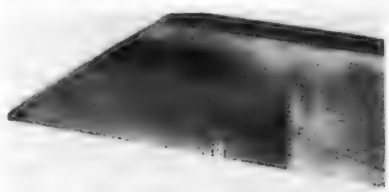

Fig. 2.—Maple board with 6-inch lag screw planed with carbide knives on 24-inch surfacer.

Most of our aircraft carrier flight decks are covered with Douglas-fir laminated with teak. These planks are usually three inches in thickness and six inches wide and average about 16 feet in length. Approximately 300,000 board feet are required for an Essex-type carrier, that is the 27,000-ton class aircraft carrier. Teak decking costs about $1.50 a board foot finished. We formerly used lignum vitae stern tube bearings in all of our large ships, but today it's phenolics. However, we still use lignum vitae bearings in our submarines. Lignum vitae is a self-oiling material and when used in seawater acts as a silence material for bearings. It is, therefore, one of the principal bearing materials used in this type of vessel. It was used in the Nautilus, which is our first nuclear-powered submarine.

Many of our wood vessels such as (AM) minesweepers require continuous laminated frames of white oak and laminated Douglas-fir sterns, keels, skegs, deck beams, and other large frame members. Some of these members are 125 feet long and are five feet in depth, so you see we have had our problems in laminating as well as machining these materials.

The Navy has many problems in machining various new abrasive materials being developed almost daily, as well as hard and tough metals in this modern age.

Films Described

Two motion pictures (shown at the conclusion of the paper) were produced by the Gordon A. Mitchell Company in Hollywood, Calif., under contract with the Navy as the producers. We shot these films in the Long Beach Naval Shipyard, aboard an aircraft carrier, and in Puget Sound Naval Shipyard. We believe these films to be the first ever produced on carbide tools used on woodworking machines. We have many similar films showing machine tools using carbides. The pictures are factual and the machines shown are exactly as they are used in the shops.

The first film shows grinding, handling, issuing, and storing of carbide tools in a woodworking shop in one of the shipyards.

The second film shows several machines in operation cutting various materials. This subject covers such a broad scope that we could not show in detail any of these operations. Actually, the films were designed and made for the journeyman in the woodworking shops. These men are familiar with the various operations and it is not necessary to go into details to show them what these operations are. We do give some of the speeds and the feeds of the machines and what the materials are. We could not go into detail as to the primary and secondary cutting angles. However, we do give a few cutting angles, and primary and secondary clearance angles. The angles are shown by animation and are merely to let the mechanics know just how much we have reduced our cutting angles and loads with carbides. We have experimented for the past five years in one of the yards with various cutting and clearance angles to determine which will give us the maximum use of our carbides on the various machines for the different speeds and feeds and the many materials that we machine. We have kept fairly accurate records on these experiments and consequently have accumulated some valuable information in this area.

The rakes, angles and hooks on the saws shown in the films are the result of many trials and experiments on the various kinds of materials.

If there were such a thing as a best cutting angle, I believe for all practical purposes, we would favor the 15° positive cutting angle for carbides when cutting the majority of the highly abrasive materials, especially where the high abrasive materials are hard and tough. Also, 15° hook on the saws would be the one that we would favor as the most practical. We started using the 30 to 35° cutting angle several years ago and have reduced the cutting angles down to 15°. However, we have gone down to a 3° positive cutting angle on a few of our real tough materials and in some cases, we have even used a negative rake. The primary and secondary back level angles which determine the clearance angles are not nearly as important to us as the cutting angle, which is the angle on the front of the tool. When we design our cutting tools, we take advantage of the compressive strength of carbides, thereby reducing the angles as much as practical and leaving as much stock as possible on the back of the tool with just enough clearance to give the cutting edges as much support as possible.

We have had many requests from industry and colleges for borrowing these films. If any organization would like to borrow them, we will be glad to arrange for the loan.

Combustibility vs. Fire Resistivity[1]

ELON E. ELLIS

Vice-President and Director of Sales, Timber Structures, Inc., Portland, Oregon

WOOD WILL BURN! How often have we heard that objection to the use of timber. No one, of course, will deny that wood will burn, but the mere act of burning is only a small part of the whole story. How well a material retains its load-bearing capacity and its original form and other physical properties when subjected to intense heat is much more to the point.

Steel, for example, will not burn. But it begins to soften at from 600 to 700° and becomes plastic at from 1000 to 1200°. At 1000°, lateral expansion of a steel member will be as much as 9½ inches for each 100 feet of length; during a fire, supporting walls frequently are collapsed or badly damaged.

In contrast to this performance is a test recently made at the Timber Structures plant. A glulam beam 9 by 27⅝ inches was subjected to an open flame in a cubicle enclosed on four sides and open at the top. Temperatures were checked with a pyrometer at regular intervals. Temperature was 500° along the sides of the beam at the beginning of the test, and increased to 1600°. Average temperature during the full hour of exposure was 1270°.

At the end of the hour, the beam was removed from the fire, the flame extinguished, and the beam cut in the center where the fire was hottest. The accompanying photo illustrates the natural insulating properties of wood which make it effective as a fire-resistive material. Dotted lines indicate the original section size. The remaining uncharred section measures 7¼ by 26 inches, which is 75.8 per cent of the original section. Based on the ultimate strength of the material, the beam is capable of continuing in service with a safety factor greater than 2 to 1.

Glued laminated beam 9 x 27⅝ inches subjected to open fire test for one hour. Dotted lines indicate original section size. Based on ultimate strength of material, the beam is capable of continuing in service with a safety factor greater than 2 to 1.

Charring along the sides is very even and there is no trace of delamination due to penetration of the fire. The lamination at the bottom of the beam was charred practically all the way through but did not drop off. Average temperature at the bottom lamination was considerably higher than at the sides of the beam.

Timber, unlike steel, does not expand laterally and thus does not push out or damage walls. Only damage to the timber is reduction in section which usually is not critical. Timbers, when left exposed, may be boxed in for the sake of appearance and continued in service.

Yes, wood will burn, but it resists destruction by fire better than any other commonly used material. Dollar for dollar of investment, wood provides much the greatest value in permanent, fire-resistive construction.

[1] Reprinted from *Tim-Press* with permission of publishers, Timber Structures, Inc.

Stiffness Factors Involved In Plywood Constructions[1]

LOUIS ROY

Sales Engineer, Reichhold Chemicals (Can.) Ltd., Ste. Therese of Blainville, P. Q. Canada

Discusses a particular engineering method involving the stiffness factor of hardwood plywood and illustrates with practical applications how this method can be helpful in selecting a plywood construction. The stiffness factor calculations are derived from those originally established in the study of metallic sheets. The derived formulae are approximate but sufficiently accurate for most engineering uses.

Introduction

THE HARDWOOD PLYWOOD INDUSTRY of Eastern Canada has now reached a stage where better engineering methods should be used to improve the control of its products, so that it can more easily compete with all the similar building materials which are offered to the North American market. Until now, a great deal of plywood knowledge has been chiefly based on experimental results. This empirical knowledge can be supplemented by the use of theoretical methods for predicting the behavior under stress of various plywood constructions.

These theoretical methods are not new, having been already described and used by a few plywood engineers. However, they were not popularized to the point of awakening the interest of all Canadian plywood people. Hardwood plywood is a well known, highly decorative building sheet which finds new uses every day, but there appears to be a great lack of information about most of its technical properties.

Preliminary Assumption

Plywood is an assembled product made of layers of veneers and adhesives, the chief characteristic of which is the coordination of cross layers distributing the strength properties of the wood. The central layer or core is sometimes made of edge-glued strips of lumber, called lumber core; it may also be a slab of artificial lumber or particle board, commonly called chipcore. Among the numerous advantages of plywood over solid wood are the following: more evenly distributed strength properties with and across the grain of the face plies, greater resistance to checking and splitting, almost negligible dimensional change with variation of moisture content. The above advantages are obtained by alternating the direction of the grain in the successive plies.

Throughout this paper, it has been assumed that all the other factors that contribute to the strength properties of the plywood panel are under good control. There are several variables in plywood manufacturing: condition of veneers or cores, moisture content, species of wood, quality of adhesion, etc. Only one of these variables is considered here—the contribution of the different veneer plies according to their thickness and wood species to the final plywood construction. The bondage will be assumed excellent, and the veneer uniform in moisture content, thickness, grain, and smoothness. Observations will relate only to the most commonly used hardwoods such as birch, elm, ash, basswood, and cottonwood.

Balanced Construction

It is known that any plywood construction to be balanced must be built up of an odd number of plies—3, 5, 7, or 9, alternate plies being of the same thickness and species. When two plies only are glued together, one ply will expand or contract in one direction, i.e., across the grain while the other ply will attempt to restrain that change. The first objective to be considered is to get a balanced plywood construction, otherwise the panel is bound to badly warp and twist.

The number of plies in the panel greatly influences its strength properties. A preliminary relationship involved is the amount of wood which is arranged with its grain in a given direction. Table 1 illustrates this point. For instance, in a regular 4- by 8-foot panel, it is possible to make a panel of 3, 5, 7, 9 plies or more. The more plies used, the closer the ratio A/B approaches unity. Where greater distributed strength is desired, i.e., in both directions parallel and perpendicular to face plies, the closer the ratio should be to one. A 9-ply panel is more desirable than a 7, a 7 more than a 5, etc. Where side and end compression and tension loads are expected, this ratio becomes very important; for most purposes, other characteristics of the panel are more dominant.

At this stage, it is realized that the number of plies can be varied and their thickness adjusted to suit a given purpose. For example, thin faces of first-class veneer can be laid over a thicker core of second-class veneer, laminated lumber, or wasteboard.

Static Bending Test

The engineering method of studying the influence of each ply in a plywood construction is to consider the static bending stresses in the plywood in the same manner as if it were a solid wood beam. The bending stresses in a solid beam are proportional to the vertical distance from the point where they occur to the center of the beam, and are proportional to the load to which the beam is subjected. This is known as Hooke's Law for homogeneous materials. The properties of plywood are definitely related to the properties of solid wood. Fig. 1 shows how this fundamental principle applies to a solid wood beam under loaded conditions.

Table 1.—RATIO OF PARALLEL GRAIN TO PERPENDICULAR GRAIN IN PLYWOOD PANELS MADE UP OF EQUAL PLIES OF VENEER

Ratio A/B	A Parallel Plies	B Perpendicular Plies
2/1 = 2:1 with 3 ply plywood	2	1
3/2 = 1.5:1 with 5 ply plywood	3	2
4/3 = 1.3:1 with 7 ply plywood	4	3
5/4 = 1.25:1 with 9 ply plywood	5	4

[1] Presented at annual meeting of Eastern Canadian Section, FPRS, March 14–16, 1955, in Ottawa, Ontario.

The Author: Louis Roy received F.E. degree from Laval U., M.F. from Yale U., was research engineer with International Plywoods and production engineer with Ste. Marie Plywoods before accepting present position in 1951. He is in charge of wood adhesives for Eastern Canada for Reichhold Chemicals (Can.) Ltd. Roy is a trustee of the Eastern Canadian Section, FPRS.

Plywood is heterogeneous since each pair of its plies may have a different rigidity. The distribution of stresses in a piece of plywood is different than in a homogeneous material such as a piece of solid wood. Homogeneity applies in an optimum solid beam which has its wood fibers parallel to the length. Fig. 2 illustrates this principle, which will govern further observations. In both cases, the strain or deformation is the same, but the stresses are quite different due to the sudden change in the rigidity of the wood at the glue line.

The moment of inertia is a well known quantity in working out a master formula to express the rigidity of a beam. Fig. 3 compares a solid wood beam to a plywood beam. The moments of inertia of the beams shown in Fig. 3 are derived as follows:

$$I = \text{Moment of Inteia} = \frac{bd^3}{12}$$

$$b \text{ (breadth)} = 12''$$

$$d \text{ (depth)} = 5/8''$$

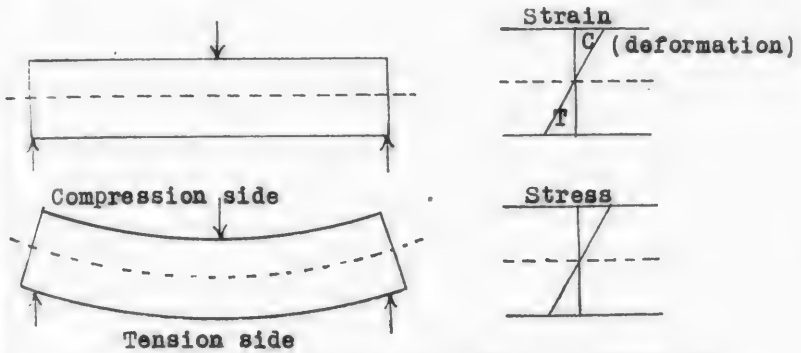

Fig. 1.—Stress distribution in solid wood beam with grain parallel to span.

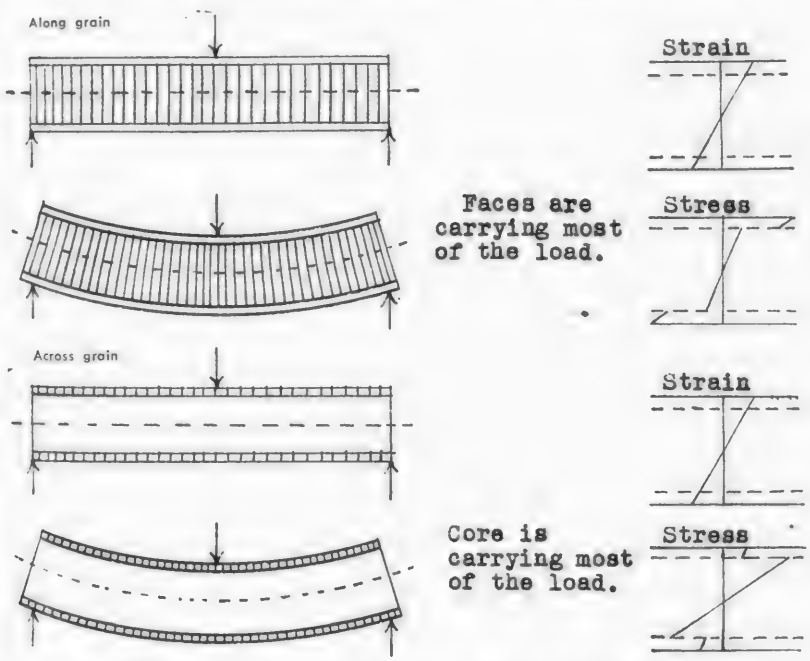

Fig. 2.—Stress distribution in a plywood beam with grain of face plies parallel to span.

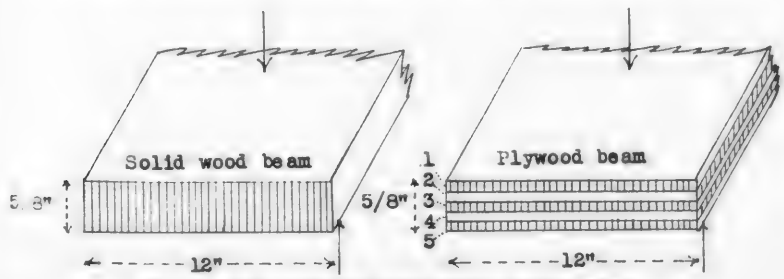

Fig. 3.—Solid wood and plywood beams in cross-section.

In Solid Wood

$$I = \frac{12 \times (5/8)^3}{12} = \frac{125}{512}$$

In Plywood

$$I = \frac{12 \times (5/8)^3}{12}$$

$$- (3/8)^3 + (1/8)^3 = 99/512$$

In the plywood beam, the longitudinal plies only—1, 3, and 5, contribute to carrying the load to any practical degree and are thus the only ones to be considered. The plywood beam carries only 99/125 or 79 per cent of the load that will be carried by the solid wood beam. Here a solid or laminated piece of wood is better than a piece of plywood.

Stiffness Factor

The measure of rigidity or stiffness is obtained by the computation of the modulus of elasticity derived from the static bending tests of small beams.

$$E = \text{Modulus of Elasticity} = \frac{P \times L^3}{4 \times b \times d^3 \times y}$$

P = load at proportional limit
L = length (span)
b = breadth
d = depth
y = deflection

Solid wood is much stiffer along than across the grain (see Table 2). The modulus of elasticity ranges from 1,330,000 to 2,150,000 psi. Across the grain, the modulus of elasticity is usually estimated to be about 1/20 of that along the grain, i.e., it varies from 66,500 to 107,500 psi. In order to obtain more evenly distributed properties in plywood, it is necessary to sacrifice, to a certain extent, the natural maximum strength properties that are parallel to the grain direction. This 1/20 ratio applies to rotary-cut veneer; in radially sliced veneer, 1/12 should be used. Most Canadian veneer being rotary cut, the 1/20 ratio was selected.

The modulus of elasticity E enters into the stiffness factor which is the basic calculation tool of this paper. Because plywood is heterogeneous, the stiffness factor cannot be broken down into the modulus of elasticity, E, and the moment of inertia, I. In order to determine the stiffness factor, the moment of inertia must be computed for each pair of plies about the center of the plywood panel and this partial moment of inertia multiplied by the corresponding modulus of elasticity. This will give a series of homogeneous terms according to the number of plies in the plywood construction. The summation of these terms will provide the mathematical expression of the stiffness factor. All computations are based on the following master formula:

Stiffness Factor = EI

$$EI = \frac{(t_1)^3 - (t_2)^3}{12} \times E + \frac{(t_2)^3 - (t_3)^3}{12} \times E + \frac{(t_3)^3 - (t_4)^3}{12} \times E + \frac{(t_4)^3 - (t_5)^3}{12} \times E + \frac{(t_5)^3}{12} \times E$$

For nomenclature, see Fig. 4.

t = Distance in inches between the extreme fibres of the symmetrical plies considered.

E = Modulus of elasticity of the plies considered.

In order to simplify computations, it has been assumed that the plywood is acting as a beam 1 inch wide in both directions, along and across grain. This means "b" in the formula $I = bd^3/12$ equals one. The plies being arranged in symmetrical pairs about the center of the panel, this formula applies to balanced constructions only.

It can be seen that in plywood there are two stiffness factors to be checked, i.e., the first one parallel to the length of the panel, and the second one perpendicular to the length.

Stiffness Factor Ratio

The ratio between the first and second factors indicates how well balanced is a plywood construction. See Fig. 5 for nomenclature.

EI_L = Stiffness factor in the longest dimension.

EI_S = Stiffness factor in the shortest dimension.

$$R = \text{Stiffness factor ratio} = \frac{EI_L}{EI_S}$$

If the stiffness factor ratio R is very high, i.e. close to 20/1, or very low, i.e. close to 1/20, we approach the conditions of natural lumber. For a square panel, the ideal constructions occur when both stiffness factors are equal: $EI_L = EI_S$ or $R = 1/1$.

This is true for square panels but not for rectangular panels. For rectangular panels, the stiffness factor in one direction should be proportional to the square of the dimension in that direction:

$$\frac{EI_L}{EI_S} = \frac{L^2}{S^2} = \text{Optimum R}$$

From this mathematical relationship, Table 3 shows optimum stiffness factor ratio R for different standard sizes of plywood panels. For instance, a long-grain 4- x 8-foot panel, to be of perfectly balanced construction, should have R = 4/1. In other words, the stiffness factor lengthwise should be 4 times the stiffness factor crosswise.

Sample Computation

As an illustration, the following are computations for two current plywood

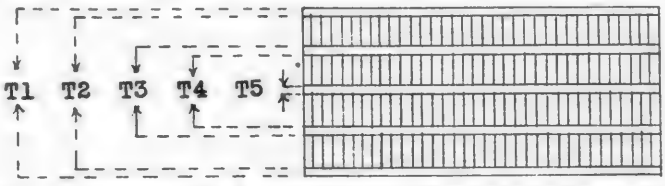

Fig. 4.—Lengthwise section for nomenclature of stiffness factor master formula.

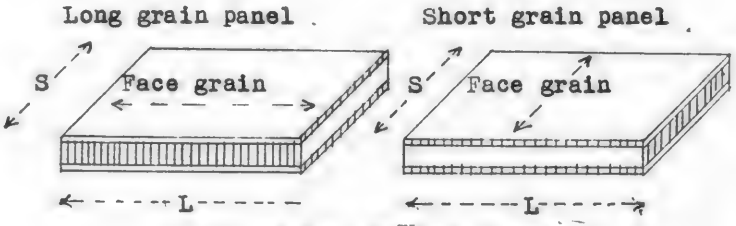

Fig. 5.—Nomenclature of dimensions. L: longest dimension; S: shortest dimension.

Long Grain Panels

$$EI_L = \frac{(t_1)^3 - (t_2)^3}{12} \times E_L + \frac{(t_2)^3 - (t_3)^3}{12} \times E_S + \frac{(t_3)^3 - (t_4)^3}{12} \times E_L + \frac{(t_4)^3 - (t_5)^3}{12} \times E_S + \frac{(t_5)^3}{12} \times E_L$$

$$EI_S = \frac{(t_1)^3 - (t_2)^3}{12} \times E_S + \frac{(t_2)^3 - (t_3)^3}{12} \times E_L + \frac{(t_3)^3 - (t_4)^3}{12} \times E_S + \frac{(t_4)^3 - (t_5)^3}{12} \times E_L + \frac{(t_5)^3}{12} \times E_S$$

Short Grain Panels

$$EI_L = \frac{(t_1)^3 - (t_2)^3}{12} \times E_S + \frac{(t_2)^3 - (t_3)^3}{12} \times E_L + \frac{(t_3)^3 - (t_4)^3}{12} \times E_S + \frac{(t_4)^3 - (t_5)^3}{12} \times E_L + \frac{(t_5)^3}{12} \times E_S$$

$$EI_S = \frac{(t_1)^3 - (t_2)^3}{12} \times E_L + \frac{(t_2)^3 - (t_3)^3}{12} \times E_S + \frac{(t_3)^3 - (t_4)^3}{12} \times E_L + \frac{(t_4)^3 - (t_5)^3}{12} \times E_S + \frac{(t_5)^3}{12} \times E_L$$

Table 2.—MODULUS OF ELASTICITY OF COMMERCIAL CANADIAN HARDWOOD SPECIES AT AIR DRIED (12%) MOISTURE CONTENT

Species	E With grain lb. per sq. in.	E Across grain* lb. per sq. in.
Yellow Birch	2150000	107500
Sugar Maple	2120000	106000
White Oak	2010000	100500
White Ash	2000000	100000
White Birch	1910000	95500
Black Walnut	1900000	95000
Red Oak	1690000	8450[illegible]
Black Ash	1660000	83000
White Elm	1610000	805[illegible]
Basswood	1400000	700[illegible]
Butternut	1380000	690[illegible]
Cottonwood	1330000	665[illegible]

* No published data regarding the modulus of elasticity across the grain could be found and its values were estimated as 1/20 of the modulus with the grain.

Table 3.—OPTIMUM STIFFNESS FACTOR RATIO FOR PANELS OF DIFFERENT SIZES

Common panel sizes			Optimum EI ratio
Lengths L	Widths S	Ratio of L/S	"R"
48″	48″	1.00/1	1.0[illegible] 1
60″	48″	1.25/1	1.5[illegible] 1
72″	48″	1.50/1	2.2[illegible] 1
84″	48″	1.75/1	3.0[illegible] 1
96″	48″	2.00/1	4.0[illegible] 1
72″	36″	2.00/1	4.0[illegible] 1
84″	36″	2.33/1	5.4[illegible] 1
6′8″	2′2″	3.00/1	9.0[illegible] 1
96″	24″	4.00/1	16.00/1

constructions: 3-ply ¼-inch, and 7-ply ¾-inch, long-grain panels.

Example of 3-ply ¼-inch, all-birch plywood. See Figs. 6 and 7 for nomenclature.

Fig. 6.—Lengthwise section of 3-ply, ¼-inch plywood (long-grain panel).

$$EI = \frac{(t_1)^3 - (t_2)^3}{12} \times E + \frac{(t_2)^3}{12} \times E$$

First Lengthwise

$$EI_L = \frac{(.250)^3 - (.170)^3}{12} \times 2{,}150{,}000 + \frac{(.170)^3}{12} \times 107{,}500$$

$$EI_L = \frac{.016 - .005}{12} \times 2{,}150{,}000 + \frac{.005}{12} \times 107{,}500$$

$$EI_L = 1{,}971 + 45 = 2{,}016$$

Second Crosswise

$$EI_S = \frac{(.250)^3 - (.170)^3}{12} \times 107{,}500 + \frac{(.170)^3}{12} \times 2{,}150{,}000$$

$$EI_S = \frac{.016 - .005}{12} \times 107{,}500 + \frac{.005}{12} \times 2{,}150{,}000$$

$$EI_S = 98 + 896 = 994$$

$$\frac{EI_L}{EI_S} = \frac{2016}{994} = \frac{2.02}{1.00} = R$$

R being equal to 2/1 means that this panel is two times stiffer lengthwise than crosswise of the face grain. If it was a short grain panel R = ½, this panel would be two times more limber across than along the face grain.

7-Ply Birch Plywood

Example of 7-ply, ¾-inch, all veneer, birch plywood. See Figs. 4 and 10 for nomenclature.

$$EI = \frac{(t_1)^3 - (t_2)^3}{12} \times E + \frac{(t_2)^3 - (t_3)^3}{12} \times E + \frac{(t_3)^3 - (t_4)^3}{12} \times E + \frac{(t_4)^3}{12} \times E$$

First Lengthwise

$$EI_L = \frac{(.750)^3 - (.656)^3}{12} \times 2{,}150{,}000 + \frac{(.656)^3 - (.300)^3}{12} \times 107{,}500 + \frac{(.300)^3 - (.178)^3}{12} \times 2{,}150{,}000 + \frac{(.178)^3}{12} \times 107{,}500$$

$$EI_L = 25{,}262 + 2{,}284 + 3{,}762 + 54 = 31{,}362$$

Second Crosswise

$$EI_S = \frac{(.750)^3 - (.656)^3}{12} \times 107{,}500 + \frac{(.656)^3 - (.300)^3}{12} \times 2{,}150{,}000 + \frac{(.300)^3 - (.178)^3}{12} \times 107{,}500 + \frac{(.178)^3}{12} \times 2{,}150{,}000$$

$$EI_S = 1{,}263 + 45{,}687 + 188 + 1{,}074 = 48{,}212$$

$$\frac{EI_L}{EI_S} = \frac{31362}{48212} = \frac{0.6}{1.0} = R \text{ or } = \frac{1.0}{1.7}$$

EI_L		EI_S		L & S	
25262 =	81%	1263 =	2%	26525 =	34%
2284 =	6%	45687 =	95%	47971 =	60%
3762 =	12%	188 =	1%	3950 =	4%
54 =	1%	1074 =	2%	1128 =	2%
31362 =	100%	48212 =	100%	79574 =	100%

Illustration

The analysis of stiffness factors in a few common plywood constructions should lead to some interesting and practical conclusions. Illustrations are given by selecting a few standard plywood constructions, most of the hardwood plywood being 3-ply, ⅛-, 3/16-, and ¼-inch thick. Curves showing relationship between stiffness factor ratio and thickness of the three veneers should be of some interest. No such relationships were studied for thicker constructions because too many different combinations are involved. Some other illustrations on ¾-inch thick, all veneer and lumber core plywood, and on 1⅜-inch flushwood door will also be briefly analyzed.

Observations on Common 3-Ply, ⅛-, 3/16- and ¼-Inch Hardwood Plywood

According to the curves in Figs. 8 and 9 showing stiffness factor ratios related to variable thicknesses of face veneers, the following remarks can be made. The different plywood combinations will be found in Table 4.

Long Grain Panels: (A) The thicker the face veneer, the more rigid is the panel along grain. The shapes of the curves prove this statement.

(B) Plywood built up of 3 equal thicknesses of veneer is very strong lengthwise, it approaches the properties of solid lumber.

¼" R = 15/1
3/16" R = 10/1
⅛" R = 7/1

A 3-equal-ply ¼-inch panel will generally be too stiff lengthwise.

In an ideal ⅛-inch or 3/16-inch door size panel, R should be between 5/1 and 10/1. Consequently a 3-equal-ply veneer construction appears highly desirable for this purpose.

(C) With face veneer thickness remaining the same, a basswood core produces a better 4-foot x 8-foot x ¼-inch panel than a birch core, if faces are not over .050-inch thick.

(D) According to the requirements of Table 3, for 4- x 8-foot all-birch panels, the optimum combinations will be, after sanding:

⅛" birch = .030" — .065" — .030"
3/16" birch = .045" — .100" — .045"
¼" birch = .055" — .140" — .055"
¼" basswood
core = .045" — .160" — 0.45"

Short Grain Panels: (A) It is impossible to build up a 3 ply 4- x 8-foot panel which will stay reasonably flat, because even by using thin faces, it will be too weak lengthwise. R can only attain a maximum value of 2/1 whereas the optimum is 4/1.

(B) The thicker the face veneer, the more the panel is subject to twisting out of shape. R drops very quickly.

(C) With the same face thicknesses in ¼-inch panels, a basswood core produces a less desirable panel than a birch core. R is lower with birch than with basswood.

Table 4.—SOME POSSIBLE COMBINATIONS OF VENEER THICKNESS IN PLYWOOD CONSTRUCTION

3-Ply ⅛-Inch Panels

Sanded faces	.015	.020	.025	.030	.035	.040
Core	.095	.085	.075	.065	.055	.045
Sanded faces	.015	.020	.025	.030	.035	.040
	.125	.125	.125	.125	.125	.125

3-Ply 3/16-Inch Panels

Sanded faces	.015	.020	.025	.030	.035	.040	.045	.050	.055	.060	.065
Core	.160	.150	.140	.130	.120	.110	.100	.090	.080	.070	.060
Sanded faces	.015	.020	.025	.030	.035	.040	.045	.050	.055	.060	.065
	.190	.190	.190	.190	.190	.190	.190	.190	.190	.190	.190

.190" instead of .186" for easy computation.

3-Ply ¼-Inch Panels

Sanded faces	.015	.020	.025	.030	.035	.040	.045	.050	.055	.060	.065	.070	.075	.080
Core	.220	.210	.200	.190	.180	.170	.160	.150	.140	.130	.120	.110	.100	.090
Sanded faces	.015	.020	.025	.030	.035	.040	.045	.050	.055	.060	.065	.070	.075	.080
	.250	.250	.250	.250	.250	.250	.250	.250	.250	.250	.250	.250	.250	.250

Table 5.—RELATIVE STIFFNESS OF EACH PAIR OF PLIES IN A 7-PLY, ¾-INCH ALL-VENEER, PLYWOOD CONSTRUCTION

	Birch (cores) Crossbands and Center			Ash (cores) Crossbands and Center			Cottonwood (cores) Crossbands and Center		
Stiffness Factor Ratio "R"	0.6 / 1.0 = 1.0 / 1.7			0.8 / 1.0 = 1.0 / 1.2			1.0 = 1.0		
Direction of Stiffness	L	S	L S	L	S	L S	L	S	L S
1/16" Sanded birch faces	81%	2%	34%	82%	3%	39%	83%	4%	44%
3/16" Crossbands	6%	95%	60%	5%	94%	54%	4%	93%	48%
1/16" birch straights	12%	1%	4%	12%	1%	6%	12%	1%	7%
1/16" Center	1%	2%	2%	1%	2%	1%	1%	2%	1%
Totals	100%	100%	100%	100%	100%	100%	100%	100%	100%

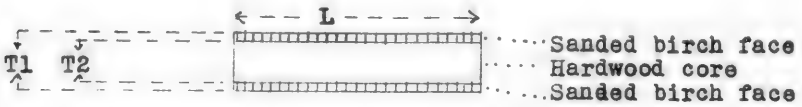

Fig. 7.—Lengthwise section of 3-ply, ⅛-, 3/16-, ¼-inch plywood (short-grain panel).

(D) The best results, which can be obtained in a short grain panel, 3-ply construction, will require the use of the thinnest possible faces, and the thickest possible core. A core species possessing a high modulus of elasticity will somewhat overcome this drawback.

Observations on an Actual 7-Ply, ¾-Inch Hardwood Plywood Panel

The next comments apply to a standard long-grain panel, built up of three different species of cores—birch, ash, and cottonwood. For nomenclature, see Fig. 10. The observations are based on Table 5, which shows the stiffness factor ratios and the relative contribution of each pair of plies to the stiffness of the panel.

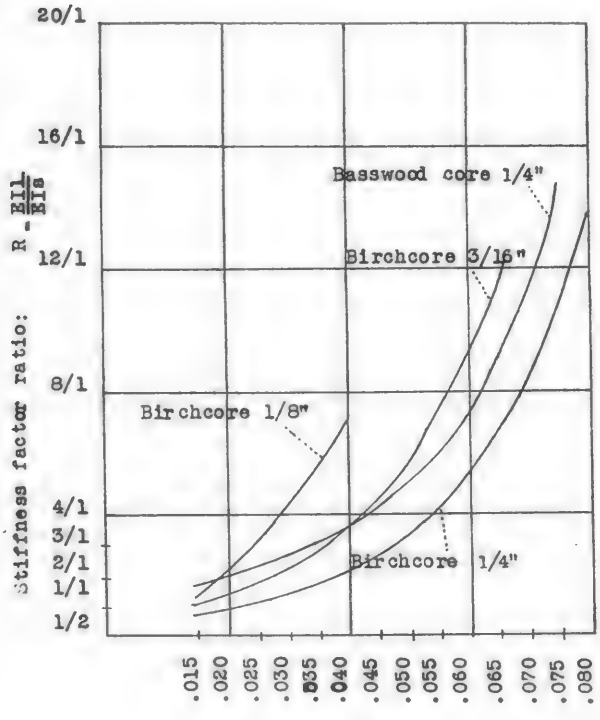

Fig. 8.—Long-grain panels.

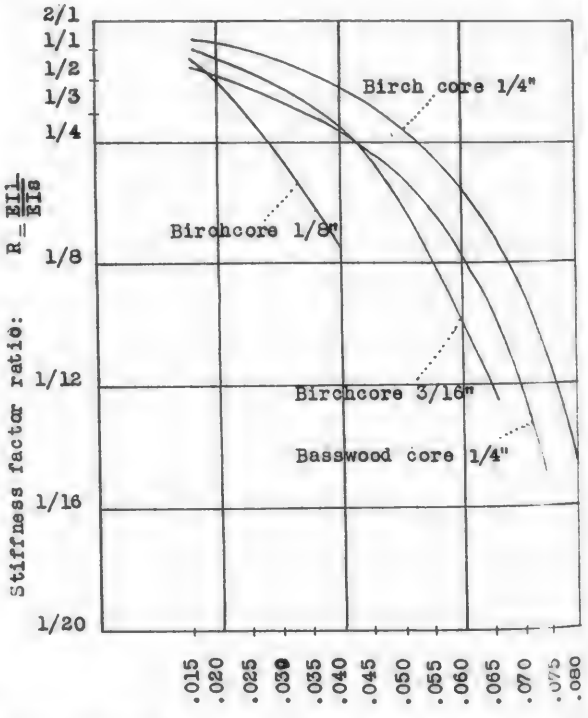

Fig. 9.—Short-grain panels.

Thickness of face veneers, after panel is sanded, both sides.

Curves showing stiffness factor ratios, R, of 3-ply ⅛-, 3/16-, and ¼-inch birch faced panels.

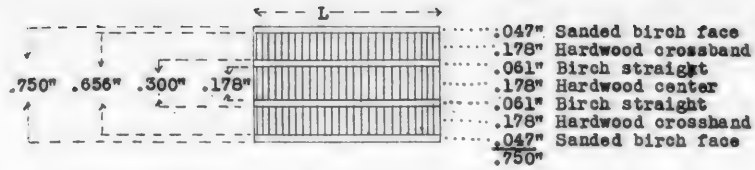

Fig. 10.—Lengthwise section of 7-ply all-veneer plywood (long-grain panel).

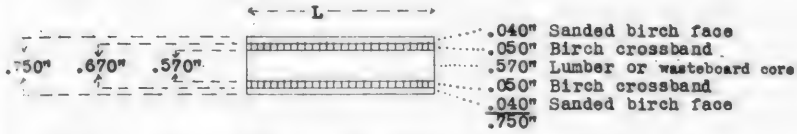

Fig. 11.—Lengthwise section of 5-ply lumber core plywood (long-grain panel).

(A) Softer cores like cottonwood give a ratio closer to 4/1: 1.0/1.0> 0.8/1.0> 0.6/1.0; consequently, for such a 4- x 8-foot panel, cottonwood cores are better than ash, and ash cores are better than birch.

(B) An average of 93% (34 + 60 = 94, 39 + 54 = 93, 44 + 48 =92) is due to the faces and crossbands (outside cores). The contribution of the straights is only about 5% (4, 7, 8), and that of the center (inside core) is only 1 to 2%. As a practical suggestion, it could be recommended to keep the better quality veneers for faces and crossbands. Straights could be made of a few pieces, simply end-to-end taped, without appreciable change in the total rigidity of the panel.

(C) With cottonwood cores (crossbands and centers), even if there is only

$$\frac{.047 + .061 + .061 + .047}{.175 + .175 + .175} = 29\%$$

of the volume in one direction, a square panel is perfectly balanced.

(D) In each case, about 94% (95, 94, 93) of the stiffness across grain is due to the pairs of crossbands.

Table 6.—ESTIMATED MODULUS OF ELASTICITY OF DIFFERENT WASTEBOARDS

Density	Modulus of Elasticity in both directions* lb. per sq. in.
Very low	50,000
Low	100,000
Medium	500,000
High	1500,000
Very High	2000,000

*Arbitrary figures.

Observations on Common 5-Ply, ¾-Inch Lumber Core or Wasteboard Core, Hardwood Plywood

A standard 5-ply construction will be illustrated, to be checked by the stiffness factor ratios computation. What influence have these thick cores such as a softwood or hardwood laminated lumber core or a wasteboard core? In Fig. 11, it is seen that faces and crossbands are of 1/20-inch thickness. Table 7 summarizes the computations of stiffness factor ratios and shows the relative stiffness contribution of each pair of plies and of the core. Because of the increasing use of wasteboard as cores, five levels of stiffness were chosen to illustrate their influence in the final construction. Table 6 gives the estimated moduli of elasticity of five possible chipcore materials.

(A) A long-grain 4- x 8-foot panel is more perfectly balanced with a birch core than with a basswood core or wasteboard core. 2.4/1.0> 1.9/1.0> 1.0/1.0: Optimum R is 4/1.

(B) The importance of the crossbands to give rigidity crosswise is quite evident: 88%, 91%, 92%, 71%, 40%.

(C) The contribution of a wasteboard core greatly increases with its density: 3%, 26%, 58%. In the case of chipcore of very low density, the rigidity of the laminated panel is chiefly due to the veneers: 48½% + 48½% = 97%.

(D) Square panels with a wasteboard core of any particular density possess a very well-balanced construction: in each case R = 1/1. This might be significant to the makers of table tops and store fixtures.

The above illustrates the two great advantages of birch veneers. A birch-faced panel is not only decorative but it also offers a great flexibility in the combination of its inner plies. The high modulus of elasticity of birch makes this hardwood species very useful in obtaining the required stiffness of a panel which, in multi-ply constructions, is mostly due to the outside plies. It offers the possibility of using inner plies of lower rigidity and less expensive wood such as elm, ash, poplar, butternut, basswood, etc.

When thick Douglas-fir, poplar panels, or particle boards are resurfaced with birch veneers, the engineering characteristics of the resulting panels are greatly improved. Birch veneers can be considered as the best species for use as skin material.

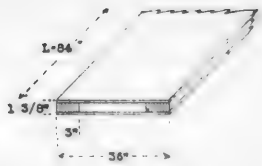

Fig. 12.—Sketch of 1⅜-inch all-birch flushwood door.

Observations on All-Birch 1⅜-Inch Flushwood Doors

A flushwood door can be considered as 7-ply plywood construction. To make computations easier, the relatively minor influence of the perpendicular solid wood frame pieces may be disregarded. It is assumed that the door measures 3 x 7 feet and the vertical stiles measure 3 inches wide; the total width of the stiles being 6 inches, they contribute 1/6 the rigidity of an alternative 36-inch wide solid core. This is illustrated in Fig. 12.

A standard long-grain door will be compared to both a short-grain door and to a 5-ply long-grain door having as a core a very low density wasteboard material. These three constructions are shown in Figs. 13, 14, and 15. The stiffness of the chipcore is purposely neglected as its contribution to the

Table 7.—RELATIVE STIFFNESS OF EACH PAIR OF PLIES, AND OF CORE, IN 5-PLY, ¾-INCH LUMBER OR WASTEBOARD CORE, PLYWOOD CONSTRUCTION

	Birch core			Basswood core			Wasteboard cores: Very low D.			Wasteboard cores: Medium D.			Wasteboard cores: Very high D.		
Stiffness factor "R" Ratio	2.4 / 1.0			1.9 / 1.0			1.0 / 1.0			1.0 / 1.0			1.0 / 1.0		
Direction of stiffness "R"	L	S	L S	L	S	L S	L	S	L S	L	S	L S	L	S	L S
1.25" Sanded birch faces	39%	5%	29%	50%	5%	34%	92%	5%	48½%	71%	3%	37%	16%	2%	21%
1.25" Birch crossbands	2%	88%	27%	2%	91%	33%	5%	92%	48½%	3%	71%	37%	2%	40%	21%
9.1" Lumber or wasteboard core	59%	7%	44%	48%	4%	33%	3%	3%	3%	26%	26%	26%	58%	58%	58%
Totals	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

stiffness of the door is approximately less than 1 per cent.

Table 8 shows the stiffness factor ratios and the individual contribution of the different door elements to the stiffness of the finished door.

(A) It appears that the best balanced construction is still the standard long-grain type; the least desirable is the short-grain type: 2.2/1.0> 1.4/1.0> 1.0/1.0.

(B) In a standard door, 83% (24 + 31 +28) of the total rigidity is due to the plywood; 90% of the crosswise rigidity is due to the core of the plywood. The great advantage of plywood as a stressed-skin material is well illustrated here, and the generally used term "door skin plywood" is evidently well chosen.

(C) In a short-grain door, 61% of the lengthwise rigidity is due to the core of the plywood. The contribution of the frame (17%) is equal to that of a standard door. 96% (45 + 51) of the crosswise rigidity is due to the faces and backs of the plywood.

(D) In a 5-ply door, the importance of the back (crossband) is great; it contributes up to 93% of the crosswise stiffness of the door. The contribution of the frame is 29%, compared with 17% in a standard door construction. With this 5-ply construction, instead of using conventional horizontal ribs, these could be placed in the vertical position in order to increase R and make it closer to 5 or 7.

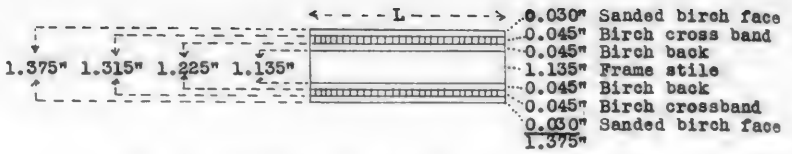

Fig. 13.—Lengthwise section of standard 7-ply long-grain door.

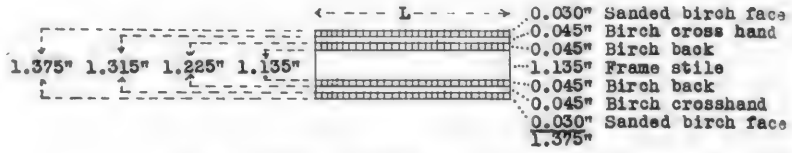

Fig. 14.—Lengthwise section of 7-ply short-grain door.

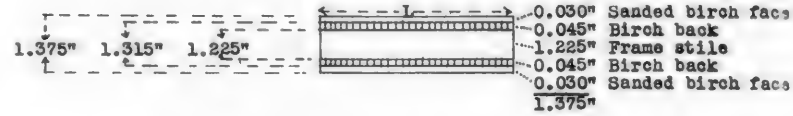

Fig. 15.—Lengthwise section of 5-ply long-grain door.

Table 8.—RELATIVE STIFFNESS OF EACH PAIR OF PLIES, AND OF FRAME, IN 1⅜-INCH HARDWOOD FLUSHWOOD DOOR

	Standard long grain faced with 3 ply plywood			Short grain door faced with 3 ply plywood			Long grain door faced with 2 ply plywood		
Stiffness factor ratio "R"	2.2 / 1.0			1.0 / 1.0			1.4 / 1.0		
Directions of stiffness	L	S	L/S	L	S	L/S	L	S	L/S
1/20" Sanded birch faces	34%	3%	24%	2%	45%	24%	50%	4%	31%
1/20" birch cores	2%	90%	31%	61%	3%	31%	3%	93%	40%
1/20" birch backs	39%	4%	28%	3%	51%	28%	----	----	----
1-9/64" or 1-12/32" birch frame	25%	3%	17%	34%	1%	17%	47%	3%	29%
Totals	100%	100%	100%	100%	100%	100%	100%	100%	100%

Conclusion

The practical examples given illustrate the theoretical calculations used. These calculations, when properly performed on the assigned values of the plywood constructions, will serve as a convenient means of evaluating the plywood construction. They will, in many cases, avoid the costly manufacture of unbalanced panels that will not perform satisfactorily. The computations might seem somewhat tedious, but they can be greatly simplified if a few working tables are drawn up. All that is required for fast computation is: a table of cubes of thicknesses, a table of the cubes divided by 12, and a table of the moduli of elasticity of the wood species involved. With these aids, within a few minutes anyone familiar with the method can determine the stiffness factor ratio of a given panel construction.

Acknowledgment

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Wooden Boxes and Crates[1]

C. O. THOMPSON

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Major species and grades of lumber used in the manufacture of nailed wooden boxes and crates are discussed. New developments in box and shook manufacturing equipment, seasoning, preservation, and trends in packaging fresh fruits and vegetables are reported. The future position of the wooden box and crate industry is projected.

MEMBERS OF THE LUMBER INDUSTRY, operating under continuous pressure to gain maximum realization from the log, have found no more universally available outlet for utilizing lower grades of sound-knotted lumber than in the production of wooden boxes, crates, and shook. This fact accounts for the high degree of integration of shook and crate production with sawmill operations, representing possibly more than 50 per cent of the nation's output of shook.

The basic advantage in the utilization of lumber of this type for container purposes lies in the wide variety of lengths, widths, and thicknesses covered by container requirements, resulting in a product of a higher grade than the material from which it was made and with minimum waste.

While utilizing these grades of lumber, however, the box, shook, and crate manufacturer is required to select those species having texture characteristics which permit mechanical nailing and high-speed resawing with minimum kerf. Furthermore, efficient production of shook requires preferably standard widths and lengths of lumber. In this connection it is important to recognize that, contrary to popular conception, it is impossible to produce, at necessary cost levels, box and crate shook solely from mill-ends, scraps, or falldowns. Box plants integrated with sawmills must assume part of the salvaging burden of such operations, but they must also be allocated the box grade portion of the log cut to sizes which permit most efficient conversion into shook or crating stock.

It is estimated that softwoods are utilized in the production of 75 per cent or more of the nation's box and crating material. Ponderosa pine and southern pine lead in over-all volume with eastern white pine, white fir, spruce, and Idaho white pine also representing important segments of the total. With shook production concentrated largely in lumber producing areas, the relative output of each species of softwood follows rather closely the pattern of lumber production.

In the New England states, eastern white pine is utilized for more than 80 per cent of the box and crate volume. Most of this production comes from what is known as round-edge lumber, that is, unedged lumber.

In Southeastern states, southern pine represents possibly more than 65 per cent of container production, with gum, poplar, and cypress accounting for most of the remainder. Standard widths and lengths of southern pine are largely utilized.

In the deep South also, southern pine represents more than 65 per cent of shook sawn with gum leading in volume among the hardwoods. Cottonwood makes an important contribution, being preferred in the production of beverage cases and egg cases.

In the North Central states—Minnesota, Wisconsin, Michigan — aspen or popple has become an important container species, with white pine continuing in demand, as available.

Mississippi Valley manufacturers of boxes and shook draw lumber quite generally from Southern and Western or Pacific Coast producing areas.

West of the Rockies, ponderosa pine predominates, although white fir has in recent years become of major and growing importance in shook production. Sugar pine, Idaho white pine, Sitka spruce, hemlock, and Englemann spruce are also used in considerable volume in West Coast areas.

Users of shipping containers have in recent years become more conscious of comparative weights of the various species of lumber, due to mounting transportation costs and with the realization that the packed container is subject to the rate applicable to the contents.

Standardization

Standarization of all types of containers is encouraged, and has been carried farthest in the field of fruit and vegetable containers. Specifications for all packages used in rail transportation of fruits and vegetables have been standardized and are set forth in four railroad tariffs which together cover interstate movements between all points in the United States. Early efforts toward produce container standardization were directed against the maze of containers in use at that time. Present standards are the result of work performed by the Association of American Railroads and interested groups of fruit and vegetable shippers and growers and container manufacturers. Rate penalties are invoked against rail shippers using produce containers which deviate from the tariff standards.

While there are no universal standards covering containers used for carrying perishables in transportation systems other than railroads, usually packages listed in rail tariffs are also utilized for highway and air systems. In addition, a few other containers enjoy a limited use for handling fruits and vegetables, each usually within a relatively small geographic area.

Standardization has also invaded other fields where the products are uniform. For instance, egg case standards, developed mainly through efforts of the U. S. Department of Agriculture, are in general use. These standards cover both domestic and export shipments of shell eggs. That these standards are kept current is demonstrated by the fact that during recent years length and width of standard 30-dozen egg case ends have been increased by one inch to accommodate larger eggs produced by American hens. Another example of wooden box standards is the poultry container specification also developed by the U. S. Department of Agriculture.

Standardization in the industrial box and crate field presents a great many problems not found in the perishable field, due to the great multiplicity of items being shipped. However, the

[1] Presented at Session V, Packaging, FPRS Ninth National Meeting, June 21–24, 1955, in Seattle, Wash.

The Author: C. O. Thompson has a broad background of experience in virtually every phase of the produce industry, from box maker and crate packer to district manager of produce shipping organizations. He joined The Wooden Box Institute in 1950 as field representative, was appointed secretary in 1952, and became president in 1954.

stiffness of the door is approximately less than 1 per cent.

Table 8 shows the stiffness factor ratios and the individual contribution of the different door elements to the stiffness of the finished door.

(A) It appears that the best balanced construction is still the standard long-grain type; the least desirable is the short-grain type: 2.2/1.0> 1.4/1.0> 1.0/1.0.

(B) In a standard door, 83% (24 + 31 +28) of the total rigidity is due to the plywood; 90% of the crosswise rigidity is due to the core of the plywood. The great advantage of plywood as a stressed-skin material is well illustrated here, and the generally used term "door skin plywood" is evidently well chosen.

(C) In a short-grain door, 61% of the lengthwise rigidity is due to the core of the plywood. The contribution of the frame (17%) is equal to that of a standard door. 96% (45 + 51) of the crosswise rigidity is due to the faces and backs of the plywood.

(D) In a 5-ply door, the importance of the back (crossband) is great; it contributes up to 93% of the crosswise stiffness of the door. The contribution of the frame is 29%, compared with 17% in a standard door construction. With this 5-ply construction, instead of using conventional horizontal ribs, these could be placed in the vertical position in order to increase R and make it closer to 5 or 7.

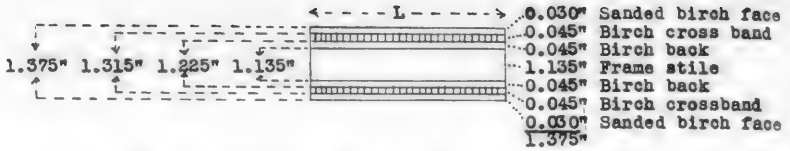

Fig. 13.—Lengthwise section of standard 7-ply long-grain door.

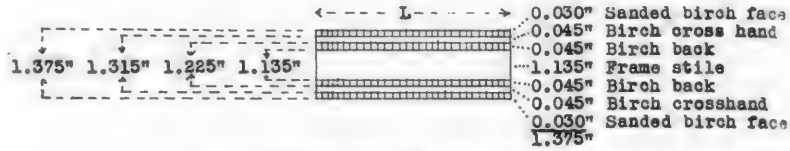

Fig. 14.—Lengthwise section of 7-ply short-grain door.

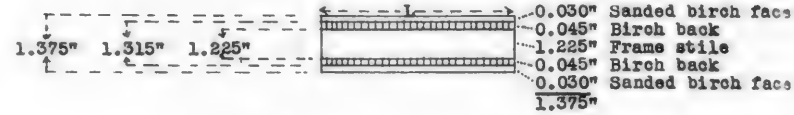

Fig. 15.—Lengthwise section of 5-ply long-grain door.

Table 8.—RELATIVE STIFFNESS OF EACH PAIR OF PLIES, AND OF FRAME, IN 1⅜-INCH HARDWOOD FLUSHWOOD DOOR

	Standard long grain faced with 3 ply plywood			Short grain door faced with 3 ply plywood			Long grain door faced with 2 ply plywood		
Stiffness factor ratio "R"	2.2 / 1.0			1.0 / 1.0			1.4 / 1.0		
Directions of stiffness	L	S	L/S	L	S	L/S	L	S	L/S
1/20" Sanded birch faces	34%	3%	24%	2%	45%	24%	50%	4%	31%
1/20" birch cores	2%	90%	31%	61%	3%	31%	3%	93%	40%
1/20" birch backs	39%	4%	28%	3%	51%	28%			
1-9/64"or 1-12/32" birch frame	25%	3%	17%	34%	1%	17%	47%	3%	29%
Totals	100%	100%	100%	100%	100%	100%	100%	100%	100%

Conclusion

The practical examples given illustrate the theoretical calculations used. These calculations, when properly performed on the assigned values of the plywood constructions, will serve as a convenient means of evaluating the plywood construction. They will, in many cases, avoid the costly manufacture of unbalanced panels that will not perform satisfactorily. The computations might seem somewhat tedious, but they can be greatly simplified if a few working tables are drawn up. All that is required for fast computation is: a table of cubes of thicknesses, a table of the cubes divided by 12, and a table of the moduli of elasticity of the wood species involved. With these aids, within a few minutes anyone familiar with the method can determine the stiffness factor ratio of a given panel construction.

Acknowledgment

The author gratefully acknowledges the assistance of Georges Roy, vice-president, Plywood Associates of Montreal, P. Q., Canada, in preparing this paper.

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Wooden Boxes and Crates[1]

C. O. THOMPSON

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Major species and grades of lumber used in the manufacture of nailed wooden boxes and crates are discussed. New developments in box and shook manufacturing equipment, seasoning, preservation, and trends in packaging fresh fruits and vegetables are reported. The future position of the wooden box and crate industry is projected.

MEMBERS OF THE LUMBER INDUSTRY, operating under continuous pressure to gain maximum realization from the log, have found no more universally available outlet for utilizing lower grades of sound-knotted lumber than in the production of wooden boxes, crates, and shook. This fact accounts for the high degree of integration of shook and crate production with sawmill operations, representing possibly more than 50 per cent of the nation's output of shook.

The basic advantage in the utilization of lumber of this type for container purposes lies in the wide variety of lengths, widths, and thicknesses covered by container requirements, resulting in a product of a higher grade than the material from which it was made and with minimum waste.

While utilizing these grades of lumber, however, the box, shook, and crate manufacturer is required to select those species having texture characteristics which permit mechanical nailing and high-speed resawing with minimum kerf. Furthermore, efficient production of shook requires preferably standard widths and lengths of lumber. In this connection it is important to recognize that, contrary to popular conception, it is impossible to produce, at necessary cost levels, box and crate shook solely from mill-ends, scraps, or falldowns. Box plants integrated with sawmills must assume part of the salvaging burden of such operations, but they must also be allocated the box grade portion of the log cut to sizes which permit most efficient conversion into shook or crating stock.

It is estimated that softwoods are utilized in the production of 75 per cent or more of the nation's box and crating material. Ponderosa pine and southern pine lead in over-all volume with eastern white pine, white fir, spruce, and Idaho white pine also representing important segments of the total. With shook production concentrated largely in lumber producing areas, the relative output of each species of softwood follows rather closely the pattern of lumber production.

In the New England states, eastern white pine is utilized for more than 80 per cent of the box and crate volume. Most of this production comes from what is known as round-edge lumber, that is, unedged lumber.

In Southeastern states, southern pine represents possibly more than 65 per cent of container production, with gum, poplar, and cypress accounting for most of the remainder. Standard widths and lengths of southern pine are largely utilized.

In the deep South also, southern pine represents more than 65 per cent of shook sawn with gum leading in volume among the hardwoods. Cottonwood makes an important contribution, being preferred in the production of beverage cases and egg cases.

In the North Central states—Minnesota, Wisconsin, Michigan — aspen or popple has become an important container species, with white pine continuing in demand, as available.

Mississippi Valley manufacturers of boxes and shook draw lumber quite generally from Southern and Western or Pacific Coast producing areas.

West of the Rockies, ponderosa pine predominates, although white fir has in recent years become of major and growing importance in shook production. Sugar pine, Idaho white pine, Sitka spruce, hemlock, and Englemann spruce are also used in considerable volume in West Coast areas.

Users of shipping containers have in recent years become more conscious of comparative weights of the various species of lumber, due to mounting transportation costs and with the realization that the packed container is subject to the rate applicable to the contents.

Standardization

Standarization of all types of containers is encouraged, and has been carried farthest in the field of fruit and vegetable containers. Specifications for all packages used in rail transportation of fruits and vegetables have been standardized and are set forth in four railroad tariffs which together cover interstate movements between all points in the United States. Early efforts toward produce container standardization were directed against the maze of containers in use at that time. Present standards are the result of work performed by the Association of American Railroads and interested groups of fruit and vegetable shippers and growers and container manufacturers. Rate penalties are invoked against rail shippers using produce containers which deviate from the tariff standards.

While there are no universal standards covering containers used for carrying perishables in transportation systems other than railroads, usually packages listed in rail tariffs are also utilized for highway and air systems. In addition, a few other containers enjoy a limited use for handling fruits and vegetables, each usually within a relatively small geographic area.

Standardization has also invaded other fields where the products are uniform. For instance, egg case standards, developed mainly through efforts of the U. S. Department of Agriculture, are in general use. These standards cover both domestic and export shipments of shell eggs. That these standards are kept current is demonstrated by the fact that during recent years length and width of standard 30-dozen egg case ends have been increased by one inch to accommodate larger eggs produced by American hens. Another example of wooden box standards is the poultry container specification also developed by the U. S. Department of Agriculture.

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development of industrial box and crate specifications, both commercial and those used by military and other governmental agencies, has been an important factor in reduction of waste in manufacturing operations.

The National Wooden Box Association, through cooperative efforts of industry members, has been a prime force in the development of realistic commercial box and crate specifications. The military, especially when acting under the great impetus given proper packing during World War II and the Korean emergency, have done much to develop standards for nailed wooden containers designed to carry items under conditions of great abuse and shipping hazards.

Seasoning

Traditionally, wooden box and crate manufacturers have considered 18 per cent moisture content as a satisfactory maximum, subject to a minimum of 12 per cent, or in some instances, 8 per cent. Brittleness and accompanying loss of strength account for the fixing of a minimum figure.

Recent recommendations by National Wooden Box Association, as formulated by its specifications committee, emphasize the position taken by many industry members on the subject of moisture content. The recommendations were invited by personnel within the Department of Defense assigned the task of developing a new military specification covering both domestic and export nailed wooden boxes, designed to supersede federal specification NN–B–621b and military specification JAN–P–106A, the current domestic and export box standards. Both require moisture content of boxes to be within the 18 to 12 per cent limit. In writing the new specification, the association has recommended a minimum moisture content of 8 per cent, based primarily on the fact that during certain seasons West Coast lumber falls below the 12 per cent moisture content limit without accompanying loss of those characteristics which make it good raw material for containers.

Developments in Box and Shook Manufacturing Equipment

Although the nailed wooden box and crate industry has been highly mechanized for a number of years, comparatively recent developments in machinery and equipment have helped manufacturers speed up their production processes and adapt their products to changing times.

One of the results of the industry's constant search for methods of redesigning containers to reduce weight while maintaining product protection has been the introduction of efficient and economical resawing equipment. Modern resaws make it possible to buy or produce thinner and at the same time more uniform lumber which, when used in combination with cleated ends, permits savings in tare weight while maintaining structural strength.

New automatic head feed attachments on box nailing machines permit apple shippers to make as many as 680 complete boxes per hour. Even faster speeds are possible on modern machines used to make smaller containers such as peach boxes. Shippers of fruits and vegetables after filling their boxes may close them automatically with units equipped with mechanical cover feeds.

A manufacturer of box equipment has recently perfected a nailing machine which, for producers of industrial boxes in short runs of many sizes, will automatically frame containers in random sizes without adjustment between sizes. Large users of nailed wooden boxes, such as the military forces, can purchase a machine with which one operator can lid up to 600 boxes of mixed sizes per hour. As boxes are conveyed into the machine, it automatically adjusts the nailing chucks to the proper size, drives the required number of nails, and discharges the lidded box onto an outgoing conveyor. High-speed steel strapping machines are available to shippers, and small users of wooden boxes or crates may purchase a semi-portable, one-shot nailer for assembling unitized crate panels and lidding boxes. Still another machine in a single operation straps and assembles beverage cases.

Trends in Packaging and Shipping Fruits and Vegetables

Three recent trends which have affected container design and usage are particularly significant. The first of these, and the one which perhaps will be most lasting, is the growing preference of retailers for smaller, more easily handled produce containers. This preference stems partly from increased employment in retail outlets of women who cannot handle large, full size packages containing such commodities as lettuce or lemons. It is also partly due to the retailer's desire to purchase perishables in smaller amounts and at more frequent intervals, thereby allowing reduction of both spoilage losses and the amount of space which must be allocated for storage.

The advent of smaller packages has posed problems for the wooden box industry. While it is true that for a smaller load a package may incorporate thinner, less expensive parts, it does not follow that two half-crates will cost the same to produce as one full-size crate. Two cost more, naturally, and it costs the produce shipper more to pack them. This cost factor has led, in turn, to the second major trend—more field packing.

Shed packing of fruits and vegetables generally results in a more closely sized, better appearing pack but is accompanied by such overhead factors as highly skilled and highly paid labor plus considerable long-range investments in buildings and machinery. In contrast, field packing utilizes cheaper help, requires far less in the way of equipment and helps speed what is usually a highly perishable product on its way to market much faster. For these reasons such crops as lettuce have been taken over practically entirely by field packing. Depending on the district, approximately 75 to 90 per cent of all Western lettuce is now field packed.

It remains to be seen whether field packing will spread to other produce items or, indeed, if it will hold onto the gains made to date. Quality control is extremely difficult under these conditions. Too, some fruits and vegetables simply should not be packed in the field. Many commodities require some type of pre-cooling either before or in process of packaging, plus supervised grading and packing if the produce is to stand up during a long haul to market. In this regard indications of dissatisfaction among some Eastern receivers who do not like the general quality of field-packed produce have been noted recently. Whether or not this discontent will prove serious enough to cause a return, or even a partial reversion, to shed packing can only be answered by future developments.

It is known, however, that field packing, particularly of lettuce, is responsible for a trend toward a lighter, cheaper type of container and has thus been responsible for challenging the wooden box industry to develop such a package. Research conducted by this industry to date indicates promising results. Newly developed containers play an important role in citrus packaging. Almost all California lemons except those packed for export are now shipped in half box size containers which are volume filled permitting substantial savings to shippers.

The newly developed containers credit a large share of their success in the lettuce industry to still another development, the trend toward cooling of produce by means other than the traditional ice. For many years ice and the water it produces upon melting have dictated use of moisture resistant containers for packing fruits and vegetables. Wood met this requirement better than any other material and as

a result enjoyed almost unchallenged acceptance.

Now, however, certain items may be cooled by iceless methods. Vacuum cooling, which reduces lettuce temperature by evaporating the field moisture from its leaves, has made great strides. No crate ice is needed for lettuce cooled in this manner. Proponents of the vacuum cooling method claim it may be expanded to serve other commodities as well, but as yet this contention remains unsubstantiated. There is in process of construction a similar cooling method which is designed to retain moisture content and thus deliver fresher appearing produce. If successful, this method while eliminating need for crushed ice within the container, will require moisture resistant packages during shipment.

Other non-ice cooling methods have failed to achieve the success won by vacuum methods. "Fan-cars" equipped with power ventilators which cool the contents of the car as it waits on siding have given some container manufacturers cause for grooming possible replacements for such standard and traditional packages as the nailed wooden melon crate. It should be noted, however, that in actual practice shippers have discovered it takes approximately six times longer to cool melons packed in cartons as compared to the cooling time for the same item packed in standard wooden crates.

Expanding Use of Field Crates

Still another noticeable trend in the handling of fruits and vegetables is the greatly increased utilization of field crates. Not only are many growers turning to wooden picking boxes because rigidity of parts permits protection of fruit from tree to packing shed despite high stacking and mechanical handling methods, but also these containers are finding a place in cold storage facilities and in some instances in wholesale and retail markets.

There has been a growing tendency particularly in Eastern and Southeastern apple growing regions to leave fruit in field crates after picking and then to send crates directly to cold storage warehouses. Like standard wooden apple boxes, field crates can be stored safely in palletized loads without danger of collapse even in the lower tiers. When apples are removed from storage, they are usually repacked in standard boxes, although during recent seasons a volume of apples has moved directly to consumer outlets in field crates which are then returned to the owner after sale of the fruit.

Box, crate, and shook manufacturers are finding that the proper use of various types of chemical wood preservatives is one of the best ways of improving their products. Chemical preservatives have many applications in the wooden box field. Undoubtedly they have reached widest application in conjunction with re-usable type containers.

The chemical industry has been responsible for development of a number of different types of preservatives, each having its own special advantages. The three most commonly used chemical preservatives are copper naphthenate, pentachlorophenol, and zinc sulfonate. Usually all are used in combination with water repellent substances. One chemical manufacturer supplying the wooden box trade claims his product to be completely non-toxic and odorless, permitting it to be used safely in connection with such re-usable food boxes as field crates.

Proper use of wood preservative chemicals will increase the useful life of wooden containers many times by enhancing the holding power of box and crate fastenings and by retarding warping, swelling, splitting and checking of parts. Advantages of using preservatives on beverage cases, milk crates, tote boxes, and other containers where it is desirable to extend package life beyone a one-trip cycle, are easily recognized.

Industrial and Military Boxes and Crates

The principal products of the nailed wooden container industry—nailed and lock-corner wooden boxes, open crates, and sheathed crates—are essentially rigid, rectangular containers. When properly designed they assure product protection despite shock or superimposed loads.

Box and crate manufacturers furnish their products in infinite number of sizes, and by adding refinements in thickness of parts, a design to offer any degree of product protection is possible. A number of specifications have been developed for commercial applications of industrial wooden boxes and crates. These specifications are usually divided into two classifications —those for domestic transportation and those for export shipments. In addition, a number of government specifications cover nailed wooden boxes and crates.

Nearly all of the wooden box specifications, commercial or military, are utilized in the same way. In order to determine proper thicknesses of box parts and proper sizes of nails for fastening these parts, it is first necessary to consider two factors: the type of load and the species of wood used in constructing the box.

The characteristics of the product to be shipped obviously influence the design of the container. These characteristics are concerned with the physical properties of the load, including weight, size, fragility, shape and capacity for supporting the container. Obviously various physical factors of the species of wood to be used in the construction of the container will affect the thickness of parts. Available species of lumber for the construction of boxes are classified, for the purpose of determining nailing schedules and thicknesses of parts, into four groups: Group I embraces the softer woods of both the coniferous and the broadleaved species; Group II consists of the heavier coniferous woods and includes no hardwood species; Group III consists of hardwoods of medium density; and Group IV woods are hardwood species of high density.

Determination of box specifications is usually made by reference to tables which, when type of load, weight of load, and group of wood are known, will indicate minimum thicknesses of box parts, width of cleats, size of nails, and style of box. Standard industrial boxes may be classified into six styles which differ in end construction. A seventh style, known as the lock-corner box, is manufactured by cutting tenons in ends and sides and then bonding the joints with glue.

A crate is composed of two ends, a base, two sides, and a top. Open crates are composed of a framework of sawn lumber. The heaviest parts are incorporated in the base which can be designed for dragging, sliding, or handling by fork lifts or slings. Principal parts are corner posts, intermediate vertical members or cross members, horizontal members, and diagonals.

Sheathed crate construction is similar to that of open crate construction except that boards, plywood, or some type of sheathing is applied to all faces of ends, base, sides, and tops, thus giving the contents complete protection from shock and the elements.

Open crates are often used for domestic shipment of such items as ranges, washers, dryers, and other appliances. Commodities weighing in excess of 1,000 pounds are also normally shipped in crates. They are usually purchased by the shipper in panel form ready for quick assembly. In modern manufacturing plants, crates are often an actual part of production lines with crate bases being affixed to products early in manufacturing processes. Addition of side, end, and top panels are then accomplished as the final assembly operation.

New techniques in materials handling methods require high stacking of materials. This situation can be met squarely only by containers which are rigidly constructed to protect their con-

tents under stress of superimposed loads. In addition, nailed wooden boxes and crates lend themselves to new palletization and unit loading techniques. Rectangular shape of this type package permits solid, secure shipping and pallet pattern with no void spaces, hence utilization of all available space. They are easily handled with slings, hand-lifts, or fork trucks.

Sometimes handling savings are realized by simplest methods. One such saving is expected from a U-shaped clip smaller in size than a book of matches. Made of ordinary strap metal, these clips fit into slots near the top and bottom of strawberry crate ends, locking one crate on top of another to simplify bundling. The fact that no special tools are needed to apply or remove the clips spells ease of use for shippers and quick inspection and rebundling for buyers. Developed by The Wooden Box Institute, this method of crate bundling will be tested in interstate shipments during the current season and upon receipt of satisfactory reports will be made available to the industry.

Future Position of Wooden Boxes and Crates

Volume of wooden box and crate production manufactured from lumber has not kept pace since World War II with the upward curve in industrial production and, therefore, the percentage of the nation's packaged products moving in containers made from lumber has declined. This does not reflect upon the merits or performance of this type container, but rather is due to the fact that shippers are zealously searching for savings in freight as well as in packaging costs. Manufacturers of nailed wooden boxes are studying every possible adjustment in methods of production and in container specifications to effect weight and cost reductions, without sacrificing the basic merits of this type of container. Without a doubt this search for ways to reduce the lumber content will yield results.

Following are some of the conclusions indicated in the progress as made to date:

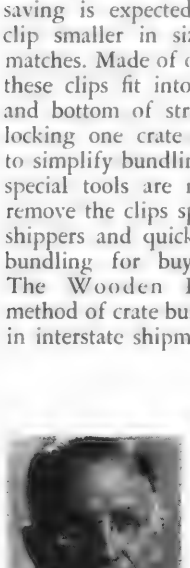
Lumber will be used to a greater degree in combination with other materials such as paper and metal in the fabrication of containers.

Adhesives will play a greater part in the unitization of parts and assembly of wooden boxes.

Standardization will be introduced to a greater extent in an effort to reduce manufacturing costs and to produce maximum shipping capacity with minimum lumber content.

Use of returnable or re-usable type boxes will be expanded, supplanting expendable or single-trip containers. Collapsible or folding type wooden boxes will increase in volume.

Automation will be in greater evidence in the machining of container parts, and in the assembly of the completed box.



The Place of Basic Courses in the Forest Products Curriculum[1]

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A broad basic curriculum in forest products on the undergraduate level should include fundamental courses in social sciences, physical sciences, biological sciences, mathematics, and English. In addition, courses specifically pertaining to the forest products field which should be included are: tree and wood identification, wood structure, mechanical and physical properties of wood, and silviculture.

TO DETERMINE the place of basic courses in the forest products curriculum, we must decide first what is meant by *basic courses* and what is meant by a *forest products curriculum.* In discussing what constitutes a forest products curriculum, there are varied opinions and my interpretation may be different from that given by others in the field of education.

At the Industry-Education Conference held at Madison, Wis., in October 1954, one of the objectives was to determine "what type of training should be offered men planning a career in the forest products industry, whether it be production, research and development, or distribution of forest products".[2] I would interpret this statement to mean that the forest products curriculum would be one broad in scope covering most of the forest products industries, and not one limited, for example, to such specialized fields as packaging, pulp and paper, furniture manufacturing, or plywood. Specifically then, the forest products curriculum will be considered here as training in the broad aspects of forest products.

Now what is meant by *basic courses?* Courses must be basic to some specific thing and in this case to training in the broad field of forest products. This being the case, there could well be included courses which would not be considered basic in other curricula such as liberal arts.

Again referring to the 1954 Industry-Education Conference at Madison, the group assigned the task of making recommendations concerning the types of training to be offered men planning a professional career in forest products stated in part: "The importance of a broad base of fundamental courses in the social sciences, physical sciences, mathematics and English were stressed. Only upon such a base can a strong professional program be built."[3] While I served as a member of this group, I feel that the biological sciences were overlooked and should have been included as a part of this base.

Broad Basic Training Is Essential

In this connection, a statement was made by Dr. H. E. Dadswell in a talk on Forest Products Research at a meeting of the Pacific Northwest Section of FPRS in Seattle on February 28, 1955. Dr. Dadswell, at the time of presentation of the paper, was a Walker–Ames Professor of Forestry at the College of Forestry, University of Washington, and was on leave from his position as Assistant Chief of the Division of

[1] Presented at Session VIII, Education, FPRS Ninth National Meeting, June 21–24, 1955, in Seattle, Wash.

The Author: Gordon D. Marckworth holds B.S. from Ohio State., M.F. from Yale U., and studied at Edinburgh U., Scotland. He was formerly head of forestry schools at the U. of Georgia and Louisiana State U. Dean Marckworth was one of 14 persons who met in Madison, Wis., on January 3, 1947, to organize the Forest Products Research Society.

[2] Panshin, A. J. 1955. Industry-Education Conference. Forest Products Journal V (1): 33.

[3] Panshin, Op. cit. p. 39.

Forest Products, Commonwealth Scientific and Industrial Research Organization of Australia. While his remarks were directed toward forest products research, he did point out what training he considered essential to produce an efficient forest products research worker. He said in part, "We find that men graduating in the physical sciences have absolutely no appreciation of the biological sciences. Yet I venture to say without fear of contradiction that the great demand today is for the biochemist and the bio-physicist. Alternatively, you can get graduates in biological sciences, particularly in botany and zoology, who have had only the bare necessities of chemistry and physics. For all research people a broad basic training is essential today".[4]

Further in his paper, Dr. Dadswell again emphasized the combination of biological and physical sciences: "The best type of training is one which contains a biological science and a physical science. . . . These combinations (botany and chemistry and/or botany and physics) are admirable for present day requirements in forest products research; the knowledge of botany making certain that the difficulties of dealing with products from living plant organisms are fully appreciated and the knowledge of a physical science making certain that present day methods of attack on biological problems can be handled efficiently and effectively. We have found from time to time that unfortunately the chemist or the physicist is completely astray in his approach to a problem because of a lack of appreciation of the biological aspects. We have also found that the fundamental study of both the structure and the chemistry of the material —wood or other products of the tree —is most essential for the best utilization".[5]

In any collegiate course regardless of its specialization, there are certain fields of study which should be included if the student is to become an educated person. First and foremost of these is English, which includes the ability to speak as well as write correctly. This is the one area in which college graduates have been most severely criticized, and it has been repeatedly pointed out that in this area the professional training of engineers, foresters, and others falls down. We are told that our graduates can't spell, that they can't write a letter or a report, and that they can't get up on their feet and talk effectively. Certainly this statement cannot be denied. However, writing or speaking can be improved over the years through practice and experience. Perhaps these latter observations are a bit aside from the assigned subject but English composition, report writing, and public speaking are certainly primary, basic courses.

[4] Dadswell, H. E. 1955. Forest products research. Unpublished paper presented at meeting of FERS Pacific Northwest Section Feb. 28, 1955.
[5] Dadswell, Op. cit.

Communications Link

In this connection, the faculty at the University of Washington College of Forestry feels that something more than English is important in insuring proper communication to employers. This link in communication might be called *engineering mindedness*. It is present when problems are clearly thought through and presented on paper in a neat orderly manner. Maps, charts, and calculations may be part of this presentation. Another way of looking at this is to point out that a student becomes a professional man only after he has acquired the professional approach to his problems. For example, enginering seems to consist more of a philosophy of solving problems than the completion of a course of instruction. One of the mainstays of this philosophy is acquired in engineering drawing, which we at the College of Forestry feel is a basic course for all students. Here the student acquires skill in two common means of communication—printing or lettering, and drawing. Other aspects of the engineering approach are acquired in the laboratory phase of forestry and forest products courses and in those taken in the engineering college. All of these help in the development of this *engineering mindedness*.

In much the same way, mathematics is a basic course for the well educated student. Some liberal arts teachers and advisers would not agree with this statement, but certainly in the forest products curriculum, algebra and trigonometry are essential tools and an appreciation of calculus is usually desirable.

In the sciences, it again should be emphasized that both biological and physical sciences are a part of the necessary foundation for a forest products major. To be specific, a thorough foundation in general physics is fundamental to many facets of the forest products industry. It is also inconceivable that any forest products student would not have a thorough grounding in chemistry including qualitative analysis and inorganic chemistry. In the biological sciences, the minimum requirement should be certain courses in botany including cell structure, plant antomy, plant physiology, and taxonomy. While a knowledge of zoology would be desirable in certain phases of the forest products industry, it is not essential as we are concerned primarily with wood which is a plant material.

Basic Economics Needed

What about the social sciences and humanities? Courses in English—writing and speaking—which we have discussed, fall within this group, but what about others? As we are training men for industry, certainly the fundamentals of economics are basic. To be of value to industry, whether in research, production or distribution, a knowledge of basic economics is essential. Perhaps a graduate engaged in fundamental research for a large forest products company or association may be completely divorced from the economic value of what he is doing. It is my feeling, however, that even under these circumstances he would be a better researcher if he understood the economics involved in his problems.

What about languages, history, psychology, philosophy? Are these basic to a forest products curriculum? I'm not sure that my colleagues in these fields could present convincing arguments for their inclusion as basic courses in our forest products curriculum, but they certainly could present arguments for their inclusion if our graduates are to have a well rounded background.

So far we have discussed seven courses in as many different fields which I believe are basic courses in a forest products curriculum. Are these all we should include? I think not, for I feel that there are certain courses which are peculiar to the forest products field. In the first place we are dealing with trees and our graduates should be able to distinguish one tree from another and in a like manner one wood from another; i.e., dendrology and wood structure. We are also dealing with the behavior of wood so the mechanical and physical properties of wood become fundamental to an understanding of other forest products courses. Finally, we are realizing today as never before that the physical properties of wood are dependent upon how the trees grow. For example, the rate of growth and character of the bole can and do affect the physical properties of the wood and may even affect the length of the fibers which go to make up the wood. To better understand this relationship, an elementary course in silviculture becomes basic.

At the University of Washington, we feel that there is a very close tie between the growing of the tree and its utilization and if the forest products graduate is to make the best use of wood, he must know something about how the trees grow and are managed, just as we feel that our forest man-

agers and logging engineers must know something about what is to become of the tree after it has been harvested.

I am sure that there will be some who will disagree with my thinking on this matter of basic courses and probably feel that certain courses which I have included should be eliminated. In a like manner, you may wish to add others. While I might argue with you about deleting some of those listed, I probably would say little if you wished to include certain others. Furthermore, there are many courses which should be a part of the forest products curriculum which are not basic to it.

Conclusions

To summarize my observations, it is my belief that a forest products curriculum should be broad enough to provide professional training for those students who are planning a career in the forest products industry and should not be confined to specialization in a limited field. The forest products graduate of a four-year curriculum is not a specialist any more than is the graduate of the conventional forestry course. Specialization will come through experience and/or graduate training. To secure such broad training, certain courses are basic. These include English, engineering drawing, mathematics, physics, chemistry, botany, economics, dendrology, wood structure, the mechanical and physical properties of wood, and elementary silviculture. How we build on this basic structure will depend upon the local problems which each institution faces and the facilities which are readily available. It is in this area that we can develop our individuality and diversity.

Discussion

Roy M. Carter (N. C. State College): The usual one-semester course in physical properties does not adequately cover wood-moisture aspects which are basic to the fabrication and use of wood. It is my feeling that a separate course dealing with wood-moisture relationships is a basic requirement in a forest products curriculum in addition to a thorough study of physical and mechanical properties.

J. S. Bethel (N. C. State College): The question of basic vs. vocational courses is always before us. Certainly vocational courses are more useful early in acquiring job experience. How can we keep a balance between them?

Dr. Marckworth: Vocational courses will always be a part of your curriculum. When you go beyond basic courses is a regional matter. The problems of the northwest are not those of the southeast. This naturally has a bearing on the course offerings of every school.

Dr. Bethel: Are there pressures to build up applied courses?

Dr. Marckworth: Yes indeed, they are always before us. If we added them all to the curriculum, then we would have the problem of determining what we must eliminate in the way of basic courses.

John Krier (Montana State U.): What is the nature of employment of utilization graduates who have had this "broad" rather than specialized training of which you speak? What are the nature of the jobs for which they are best suited?

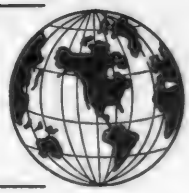
Dr. Marckworth: Apprenticeships, so to speak, in research, technology development, and selling. We have several graduates working for glue companies, plywood firms, etc. If you can get the right man in the right job, he quickly builds up confidence for other men.

J. R. Roberts (Weyerhaeuser Timber Co.): Forestry students are educated so broadly that it is difficult to fit them into technical jobs. Is it not possible to give them a more specialized course like those in engineering where the field is broken down into its several branches of specialization?

Bror L. Grondal (U. of Washington): I take issue with this gentleman, and the record speaks for itself. In the use of mechanical equipment in the woodworking industries, graduate wood technologists have made more improvements than the engineers. I emphatically deny the implication that forest products graduates have not done a good job in industry.

M. H. Mater (Mater Engineering): I should like to make a few off-the-cuff remarks relating to Dr. Marckworth's paper. I feel that the forest products industry is fortunate in the direction the undergraduate education has taken in the forestry schools. The broad-gauge plan of including English, math, biological and physical sciences gives a man a background that fits him to be an executive in the industry. Other industries worry a good deal about how to get trained executives; it is a rare engineer, chemist, or physicist who can leave his calling and become an executive, yet most other industries often pick their top men from these fields. The forest products industries have not recognized these forest products graduates as coming executives, but now that the industry is "growing up", I think the worth of such men will soon be appreciated.

Around the World in Forest Products Research and Development



Australia

• It would seem that those in the U. S. and Canada are not the only wood industries with increasing competition from other materials. J. D. Boyd, Australian Forest Products Laboratory, suggests a course of action to increase the sales of structural lumber.

Competitive materials are defeating timber because their suppliers provide a customers' service. They find out what structural performance the user wants, and they satisfy the requirement with their material, at a competitive cost; then, to make their story widely known, they go out and sell.

With effort and drive some of the field lost to steel and concrete can be regained, but it needs hard work and courage. Every year the customer's time becomes more important to him. He wants to buy guaranteed lines which can quickly be prepared for use, and for which he need not study technicalities or organize elaborate labour. He would be interested in packaged lines of timber construction such as garages, shelters, and barns. Modern modular planning and the use of standard panels for roofs, walls, and floors could have a big market. Scientifically designed construction to use the minimum but adequate amount of material is required. Roof trusses, beams, built-up frameworks, arches, and portal frames could have very wide appeal and be most profitable.

To sell these products, however, you must be prepared to provide architects and engineers with a guarantee of the quality of the construction and the adequacy of its performance. Consideration must be given to the adaptability of particular units to a variety of designs, to ease of handling and fixing on site, and, to competitive cost. To do this you must employ skilled engineers as designers, as factory-production men, and as contacts with engineers and architects on technical matters. Only so will your organization understand the outlook and requirements of structural designers and customers and be in a position to supply their needs satisfactorily and efficiently. Only so can you meet and overcome the competition of steel and concrete in the field of traditional timber usage.

—C.S.I.R.O. Newsletter

Sweden

• The Boliden Mining Company announces that a new method of wood impregnation has been working satisfactorily for over two years, with both pine and spruce wood. It is called the pressure-change method and is designed specially for conifer wood. The tracheids of conifers are connected by pit membranes acting as sort of spherical valves for the transmission of the trees' sap stream. Since preservative liquids introduced lengthwise to the wood under constant pressure will block them and hamper the permeability of the wood, it is necessary to apply pressure and vacuum alternately, so that the passage is released for a moment, allowing a small quantity of preservative to enter the valve spheres.

For best results the amount of over- and under-pressure, the duration of the periods, and other factors must be carefully controlled. Tests have shown that, since the complete process of filling the wood tracheids with the preservative liquid does not run uniformly, the frequency of the pressure-vacuum period must be kept changing according to a specific program, which is governed by the combination of a filmband, a photo cell and devices to steer the pressure pumps. Under normal conditions, the time required for the full impregnation of wood does not exceed 20 hours, in which time roughly 800 vacuum-pressure periods are applied.

The particular advantage of this new method is that even green and wet pine wood can be impregnated, so that the operation becomes independent of the seasons and weather conditions. A disadvantage is the relative length of the full process. The necessary apparatus can be attached easily and cheaply to preservation plants of the traditional pressure type.

A EUROPEAN CONTRIBUTION

Elastic Wedges—A New Development for Sash Gang Saws[1]

G. HVAMB

The Norwegian Institute of Wood Working and Wood Technology (Norsk Treteknisk Institutt), Blindern, Oslo, Norway

Analyzes a new device developed in Europe for use in tightening sash gang saw blades. It consists of a steel wedge slotted to provide a calculated elasticity, so that operating stresses in the saws and frame are better controlled, over-stressing is minimized, and setting up is facilitated. The wedge's characteristics and methods of use are described.

Introduction

L. H. REINEKE[2]

THE SASH GANG SAW, or frame saw, is of growing importance in the sawmilling industry in the United States, but our relatively limited experience with this type of saw is not sufficient, as yet, to cope with some of the problems attending its use. Scandinavia and parts of Europe, however, have a long history of successful use of such saws and it is only natural that improvements in their design and use should issue from this area.

The problems of proper installation of saws in the sash or frame, saw damage, and cutting accuracy, have engaged the attention of the sawmilling industry abroad for a long time. Improvements have been made continously, and eventually these have found their way to the United States and Canada. In recent years, several

[1] Translation of Elastic Tighteners for Framesaw Blades. Technical Note 11, Norwegian Institute of Wood Working and Wood Technology, Dec. 1955. Translated by L. H. Reineke.

[2] Technologist, U. S. Forest Products Laboratory, Madison, Wis.; now in Norway as Fulbright Research Scholar at Norsk Treteknisk Institutt, Blindern, Oslo.

types of hydraulic tensioning devices for uniformly tightening the blades in the frame have been introduced, but these have not been a panacea for all framesaw difficulties.

Calculated Elasticity

A new device has appeared on the market, originated in Germany and cooperatively tested recently by the Norwegian and Swedish Forest Products Laboratories under industrial and laboratory conditions. Called an elastic wedge, this simple piece of equipment is merely a steel wedge of the type commonly used for mounting gangsaw blades, made of special alloy steel and modified by a slot about two-thirds the length of the wedge, placed centrally between the upper and lower wedge surfaces. This slot provides a calculated elasticity to the wedge, so that operating stresses in the saws and frame are better controlled, over-stressing is minimized, and setting up is facilitated. The weight of reciprocating parts is not increased, and blades of different widths can be used in the same set-up.

A concise analysis of this new equipment, its characteristics, and method of use is contained in a technical note issued by the Norwegian Institute of Wood Working and Wood Technology, a translation of which is given below. A more detailed account of the test procedures and results is given in a bulletin from the Swedish Forest Products Research Laboratory. These publications are recommended to all present and potential framesaw users in the United States. The firm of Söderhamns Verkstäder A. B., Söderhamn, Sweden, is licensed to supply these wedges. So far as known at present, no American distributor has been appointed.

Elastic Tighteners for Framesaw Blades

G. HVAMB

The elasticity in the sawblades, in the upper and lower hangers, and in the sash or moving frame of framesaws are of considerable importance in the distribution of stresses developed in the blades and frame in the setting up of the sawblades. By the same token, this elastic quality has a decided effect on the changes in stress during cutting due to temperature changes, kinetic energy forces, and cutting forces. The elastic properties or dimensions of the sash and blades cannot be changed greatly, because they are, to a large degree, determined by a series of factors that will not be gone into here. The saw mounting or stretching

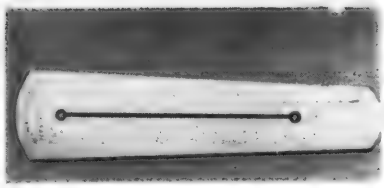


Fig. 1.—The elastic wedge.

equipment, however, is not limited to the same extent. This is safe ground on which to undertake certain experiments directed toward improved stretching devices and studies of stress conditions in the blades and moving frame system. Thus, on the continent in recent years, a number of hydraulic saw tightening devices have come into use. So far, these have not completely solved the problems of setting up the saws, as they apply a uniform load to all blades. When, for example, blades of different widths are used in the same set-up[3] the relative stress is not the same in all blades. Such apparatus as has come on the market is, moreover, quite heavy. This results in greater kinetic energies in a system which is already very highly stressed under the high reciprocating and feed speeds used in all Scandinavian framesaw mills.

Most of our [Swedish][4] framesaw mills use the ordinary cam or eccentric saw hangers, although screw hangers are used in some cases. These hangers give an unyielding stretching system and are encumbered with a number of deficiencies.

[3] In Scandinavian practice, narrow saws are commonly used in the outer positions, where the depth of cut is less because of the rounding of the log. Translator.

[4] Insertions by the translator are enclosed in brackets.

Fig. 2.—An elastic wedge in position in a cam or eccentric hanger.

a. In the first place, the tightening of each blade affects the others to a great degree. The blades must be gone over and further tightened many times before a passable similarity in blade tightness is obtained.
b. Despite careful retightening, there is little possibility of controlling the magnitude of the stress in the blades.
c. Local temperature changes in the sawblades or frame, as well as external temperature variations, affect the tightness of the blades. Local temperature changes in the blades always arise during cutting, and sash temperature rises from the heat generated as the sash moves up and down the guides. It has been proved that these blade temperature changes are quite important and larger than generally believed. Even the smallest change of stress may result either in a slack blade and inaccurate cutting or, conversely, in breakage of the blade or hanger.
d. When the blades are removed from the frame, the blade that is removed last may easily be overstressed. Sooner or later this may entail blade failure, hanger failure, shifting of the blade fittings, or the like.

To improve these conditions, it would seem only natural to incorporate an elastic member in the hangers. Elastic hangers of more or less good design have been made recently. The simplest of such elastic elements in hangers is the slotted wedge [of alloy steel] illustrated in Fig. 1. Its use in combination with an eccentric hanger is shown in Fig. 2. These wedges are patented and manufactured by the firm of Herbertz & Schmidt, Remscheid-Hasten, Germany.

Investigation of these wedges seemed desirable. Accordingly, in cooperation with the Swedish Forest Products Research Laboratory, study of these tension wedges under practical operating conditions was conducted during the past summer at one Norwegian[5] and two Swedish framesaw mills. Wedges and hangers for the tests were kindly provided by the manufacturer.

In connection with these studies, the Swedish Forest Products Research Laboratory has made a series of measurements at two Swedish framesaw mills, in addition to laboratory measurements. These are discussed more fully in a bulletin of the Swedish Forest

[5] The wedges were demonstrated in practical operation, at the Mathiesen-Eidsvold Company's sawmill, and discussed during the May 1955 summer excursion of the Society for the Advancement of the Woodworking Industry and the Norwegian Institute of Wood Working and Wood Technology.

Products Research Laboratory (1, 2). At the two Swedish mills, the change in total stretching load or force on each blade between the start and finish of the operating period (about 4 hrs.) was determined by means of strain gauges and electronic measuring instruments. The streching forces also were measured when using the ordinary eccentric and screw hangers. The results of these measurements are given in the following tables, taken from the bulletin mentioned above.

Change in stretching force between start and end of shift. [Plus sign denotes increase.] Measurements taken after wedges had been in daily operation for about one month.

Mill	Blade No. (from left of frame)	Normal eccentric hanger	Eccentric hanger with elastic wedge
		kg	kg
A	1	+ 620	— 70
	2	210	+ 70
	3	-2200	-230
	4	+1600	0
	[Av. change	± 1022	± 92.5]
		Screw hanger	Eccentric hanger with elastic wedge
		kg	kg
B	1	+ 220	—150
	2	+ 520	- 80
	3	+ 880	+160
	4	- 70	0
	5	+ 740	+140
	6	+1300	—140
	[Av. change	± 622	±112]

From the above it is evident that stresses changed much less during the course of the shift when operating with elastic wedges. This means that lower setting-up forces can be used when operating with an elastic element, without the risk of getting slack or overly tight blades during the cut, which may occur with plain hangers. Obviously this is an advantage for both frame and blades. The following table gives the average initial stretching forces, and their spread, for the blades used.

Mill A	Normal eccentric hanger	5240 ± 480 kg*
	Eccentric hanger with elastic wedge	5080 ± 360 kg
Mill B	Screw hanger	6400 ± 890 kg
	Eccentric hanger with elastic wedge	5430 ± 620 kg

*1 kg = 2.2 lbs.

It is apparent that the stresses were greatest with the screw hangers and least with the elastic wedges. The difference between eccentric and screw hangers, however, may be due to a difference in setting-up practices at the two mills. Nevertheless, the spread in values shown above indicates that it is easy to tighten the blades more uniformly when the elastic wedge is used.

Sawyers who have used wedges feel that setting up is faster and easier with the elastic wedges because it is not necessary to go over the blades so often, in retightening, to get all blades acceptably stressed. The tightening is also milder than with ordinary hangers. Furthermore, the cutting itself proceeds better, since the frame does not have to be stopped for retightening because the "set-up has settled down" in the cutting process. Another advantage is that despite the ease of clamping, the eccentrics and wedges never back off slightly as they do with the ordinary eccentric hangers. This is a result of the squeezing together of the elastic wedge, producing a slight curve that counteracts slippage. As a measure of the setting-up stress, the width of the slot in the wedge may be used. Slot width is measured easily with a conical or wedge-shaped feeler. With normal tightening and normal blades, the slot is pressed together about 0.9 mm when the load is at the center of the wedge.

A combination of screw hangers and elastic wedges is preferable because the large range of adjustment of the screw makes it possible always to place the load at the center of the wedge. This is not always easy to do with eccentric hangers. Adjustment to the desired tightness, that is to a certain compression of the wedge, is also easier to accomplish with screw hangers.

For a more complete understanding of the properties of the three types of hangers, laboratory studies were made at the Swedish Forest Products Research Laboratory. The significant results of this research are here reported briefly. The elasticity of the slotted wedge naturally is somewhat better at the center than at the ends. It is, however, better at the small end than at the wide end. Fig. 3 illustrates graphically the superior elasticity at the center. In practice, then, it is advisable never to drive the wedge too far in when setting up. Then too, the wedge should always be driven in with a special mallet of wood or plastic to avoid damage to the wedge. The slot in the wedge will be practically closed with a load of 9–10 tons[6] in the blade. This, however, is about twice the usual load. If the wedge is so heavily loaded that the slot is closed, the wedge cannot function other than as a solid wedge. It is understood, of course, that complete closure is that state at which the elastic effect of the wedge disappears. As soon as the load decreases, however, the wedge will regain its elastic property. This has not always been the case with earlier types of elastic hangers.

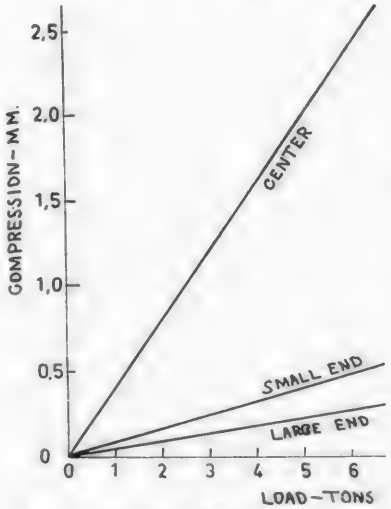


Fig. 3.—The large difference in elasticity between the center and ends, as measured by the compression or closure of the slot, shows the desirability of having the wedges centered in the hangers at the final stage of tightening.

Studies in practice also have shown that the ordinary eccentric and screw hangers have equally poor elasticity, whereas the higher elasticity of hangers with elastic wedges results in smaller variation of stresses as the stretched blades are tightened or slacked off in setting up or removing them. Above all, the sequence in which the blades are loosened and removed must be that in which there is minimum stress build-up in the saw removed last. If, for example, blades are slacked off from both sides, leaving the center blade until the last, a load increase of around 60%, ordinarily 1500 kg, often will result. The proper procedure is to slack off the blades in sequence from one side. Furthermore, the blades should always be slacked off if the set-up is to remain in the frame overnight or for a longer period.

In studying the properties of hangers during changes in local blade temperatures, single blades in the set-up were heated locally to 70–100° C. by electric heating elements. As expected, the stress changes were least in blades with elastic wedges. When the stress in blades with the ordinary eccentric and screw hangers dropped 10%, the stress in blades with elastic wedges dropped only 6%.

In view of the evidence presented here, hangers with elastic elements are recommended for use in framesaws.

Translator's Note: Fig. 2 corresponds to Fig. 1 in the original Technical Note. Figs. 1 and 3, provided by the Norsk Treteknisk Institutt, and reference 2 have been added for a fuller presentation.

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1. Thunell, Bertil. Nagra synspunkter pa inpostningsdonen i ramsagar. Bul. 76 B. Svenska Träforskningsinstitutet, Träteknisk. avd. Stockholm ö, Sweden.
2. Thunell, Bertil. Same, with English Summary. *Papper och Trä*, 37:12 p. 559. Dec. 15, 1955.

[6] [For the size of wedge tested. Other sizes are available.]

Abstracts From Current World Literature

Glues and Gluing

Adhesion and adhesives: fundamentals and practice. Papers to the Society of Chemical Industry, 22–4 April 1952, and the Case Institute of Technology, 24–5 April 1952. Society of Chemical Industry, 1954.

This volume contains the full reports of two conferences held almost simultaneously, one of which was summarized in Bulletin No. 11 (E124). In the first part of the book various aspects of the fundamental principles of adhesion are dealt with. In a paper on the types of bonds involved, F. W. Reinhart emphasizes that a smooth wood surface gives a better bond than a roughened one. H. Grinsfelder reviewed the allied subject of the bonding of surface coatings and the various causes of failure. Much of this section is of a theoretical character, but obviously forms the basis of the practical applications discussed later.

The second part consists of reviews of the adhesives used in various industries and some of the practical problems encountered. Of interest to the furniture industry are the sections on adhesives for wood (R. F. Blomquist, E. A. Davies), for glass (L. L. Yaeger, F. Moser), on animal glue (R. B. Drew), on resin and rubber emulsions (L. H. Griffiths), and on testing (G. W. Koehn, A. G. H. Dietz, L. Gilman). [F. D. C. Tech. Bul. V. 5, No. 27]

Veneer and Plywood

S. B. Preston. The effect of synthetic resin adhesives on the strength and physical properties of wood veneer laminates. Yale University School of Forestry, Bull. No. 60, 1954.

This paper describes an investigation designed to establish the extent to which the tensile and flexural strength and certain elastic properties of laminates of thin yellow popular veneer are influenced by the fundamental properties of synthetic resin glue lines. The study is limited to the properties of veneer-resin systems assembled from only one species and six commercially important types of synthetic resin adhesive, but the information disclosed can be considered basic to most veneer-resin laminates and the theories and techniques disclosed should prove useful in further fundamental glue-line studies.

The work included investigations of the apparent moisture content, modulus of rupture, elasticity and tensile strength of plywood and laminated wood, and in most cases the results are compared with those for solid wood.

Laminates bonded with phenolic adhesives have the greatest strength-weight efficiency, but this efficiency is superior to that of solid wood only in ultimate tensile strength and modulus of rupture. The influence on the properties of wood of synthetic resin adhesives differs basically from that of impregnating resins of small molecular size. The mechanical properties of veneer laminates indicate that wood adhesives do not appreciably impregnate the cell wall.

The study has demonstrated that the properties of plywood can be predicted with reasonable accuracy when the properties of laminated wood of the same veneer thickness are known. Before this method can be used extensively in design practice, however, further investigation is needed to provide methods of predicting the influence of fundamental glue-line properties of laminated veneers. [F. D. C. Tech. Bul. V. 5, No. 27]

Finishing

E. B. Gallaher. The effect of moisture on the work value of glue-bonded coated abrasives. Glover Mfg. Co., U.S.A., Bull. No. 5, 1946.

Glue-bonded coated abrasives work best when the relative humidity is 50%. When the relative humidity is too high the backings stretch, the cutting rate is slow and production is low; if the relative humidity is too low the cutting rate will be good at first, but will fall rapidly, the flexibility will decrease, the grit will tend to shed and production will again be low. Below 25% relative humidity glue bond failure is permanent.

Savings as high as 25% are claimed by users of coated abrasives who have installed storage cabinets with controlled humidity. Not only does the abrasive itself do more work, but there is also a saving in labour required for changing worn-out belts. Two small and easily constructed cabinets suitable for this purpose are illustrated.

Most of the troubles which arise during sanding are caused by incorrect moisture content of the coated abrasives, too much pressure or too low a surface speed. [F. D C. Tech. Bul. V. 5, No. 27]

Preservation

Ellwood, E. L. Effects of high pressure impregation on sotfwoods. *For. Prod News Lett. C.S.I.R.O. Aust.* No. 205, 1955 (2–3).

In pilot tests on 31 Eucalypts and 16 non-Eucalypts, collapse following creosote pressures of 1000 lb./sq. in. at 15° F occurred only in the low-density softwoods (Spruce and King William Pine). Standard treatments are up to 250 lb./sq. in. The schedule recommended for small round poles of Swedish Spruce is 400 lb., 2½ hr., 150°. For sawn Douglas Fir, the best penetration and retention commensurate with the highest pressure and shortest time without collapse was obtained at 300 lb., 2 hr., 130°. Retention was 11.9 lb./cu. ft. compared with 14.3 for treatment at 150 lb., 5 hr., and 190°, but in the latter there was some collapse. Research proceeds on the treatment of the more impermeable softwoods with higher pressures and shorter times. [For. Abs. V. 16, No. 4]

Walters, C. S., Zuckerman, B. M., and Meek, W. L. The effect of oak wilt on the cold-soak treatability of oak fence posts. *J. For.* 53 (5), 1955 (356–8).

Black and red oak posts cut from (*a*) wilt-killed and (*b*) sound trees were air-seasoned and soaked for 48 hours in a fuel-oil/pentachlorophenol solution. Absorption in the (*a*) and (*b*) posts averaged 2.8 and 4.1 lb./cu. ft., and sapwood penetration 91 and 70% respectively. Both absorption and penetration varied less in the sound posts. Wilt-induced tyloses in the sapwood (not normally present in the Red Oaks) appear to inhibit absorption. For affected timber the soak should be 72 hours. [For. Abs V. 16, No. 4]

Seasoning

Ogura, T. Effect of temperature on the moisture conductivity in wood and on the strains developed in wood as it dries. *Bull. For. Exp. Sta. Meguro, Tokyo.* No. 77, 1955 (35–68).

Using the same material (*Quercus borealis*), technique and laboratory as J. M. McMillen (see Forest Products Journal V (1): 71) the effects on drying of temperatures of 95, 110, 125 and 140° F. are detailed. The 5-page English summary and 3-page appendix on formula calculations deal with coefficients for evaporation at constant drying rate, moisture diffusion, moisture conductivity, strain pattern, moisture distribution at maximum strain, magnitude of maximum strain, immediate stress and strain and permanent set, and core in kiln operation. [For. Abs. V. 16, No. 4]

Barclay, R. M. The effect of the middle lamella and anatomical structure on the tangential shrinkage of hardwoods. *J. Oxf. Univ. For. Soc. (Ser 4)* No. 3, 1955 (5–8).

The experiment provides further proof of the feasibility of using thin sections for

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The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiber board and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

FORESTRY ABSTRACTS, published quarterly by Commonwealth Agricultural Bureaux, Farnham Royal, Slough, England, subscription price $8.40 per year. The abstracts are prepared by the Commonwealth Forestry Bureau, Oxford, England, and include a Forest Products and Utilization section. This section contains over 1,500 titles and abstracts per year from literature in some 30 languages, covers all aspects of forest utilization.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

studying shrinkage and shows that: (1) Shrinkage of thin sections of 11 hardwoods showed no relation between the number of radial middle lamellae and the degree of tangential shrinkage. (2) A significant positive correlation was observed between tangential shrinkage and the % of vessel tissue. (3) Some indication was observed of a negative correlation between tangential shrinkage and proportions of ray tissue. [For. Abs. V. 16, No. 4]

Fiber Structure

Bucher, H. Structural discontinuity of native fibers; lamellar structure of the fibers of woody tissues, and differentiation of the tertiary wall. *Assoc. Tech. Ind. Papetière,* Bull. 4–5: 95–104 (1955).

The heterogeneous microscopic structures of spruce and pine fibers are discussed with special emphasis on the so-called "tertiary layer," which is stained deeply by Victoria blue B and then made manifest by swelling the fibers in cupriethylenediamine solution. 25 photomicrographs (4 in color) and 36 references. [Bul. Pap. Chem. V. 26, No. 3]

Wardrop, A. B., and Dadswell, H. E. The development and structure of wood fibres. *Australian Pulp & Paper Ind.,* Tech. Assoc. Proc. 8: 6–23; discussion: 24–6 (1954).

Information on the development of primary and secondary walls of wood fibers is reviewed, paying particular attention to the texture of the cell wall and to theories regarding lignification. The relationship between the size of microfibrils as revealed by electron microscopy and that of micelles determined by x-ray methods is discussed on the basis of the possibility of a paracrystalline region surrounding the micelles. Some indication is given of the mechanism by which it is considered that the primary wall develops during cell extension and radial expansion. Reference is also made to the observation that thickening of the secondary wall progresses gradually toward the cell tips. Possible mechanisms for lignin deposition during cell differentiation are discussed, and it is pointed out that in certain cells of the angiosperms, such as tension-wood fibers, there is a definite lack of lignification in comparison with other cells in the same wood sample. Mention is made of the possibility of some correlation between degree of cell-wall lignification and the grinding quality of eucalypt woods used for ground-wood. [Bul. Pap. Chem. V. 26, No. 3]

Balashov, V., and Preston, R. D. Fine structure of cellulose and other microfibrillar substance. *Nature, Lond.* 176 (4471), 1955 (64–5). [Botany Dept., University of Leeds.]

Electron-diffraction study of *Valonia* cellulose and other substances seems to show that there may be some principle of structure conferring special stability in fibres ca. 200 Å. thick. The microfibril of cellulose might then be not a biological, but a thermodynamic, unit. [For. Abs. V. 16, No. 4]

Chemical Utilization

Glaser, H. Utilization of wood by methods that destroy its structure. *Kleine Schriftenreihe des Holz-Zentralblatts. Stuttgart* No. 3, 1954.

A pamphlet containing chapters on: wood pulp; sulphite and sulphate cellulose; fibreboards and chipboards; sugar from wood; destructive distillation; firewood; and gas from wood. [For. Abs. V. 16, No. 4]

Logging

Something new in pulp log towing. *Paper Tr. J.* 139 (15), 1955 (27–8).

Describes a new log-carrying barge, 342.8 ft. long, with a 63-ft. beam, capable of carrying as large a load as is assembled in a normal Davis raft. For unloading, four 8-in. valves are opened, allowing sea water to flood two tanks along the port side of the barge, so that logs slide into the water under their own gravity. The valves are then reversed, the tanks emptied, and the barge returns to normal equilibrium. [For. Abs. V. 16, No. 4]

Tennas, M. E., Ruth, R. H., and Berntsen, C. M. An analysis of production and costs in high-lead yarding. *Res. Pap. Pacif. Nthwest. For. Range Exp. Sta.* No. 11, 1955.

Factors influencing production and costs in an operation in a 100-year-old [conifer] stand on the Cascade Experimental Forest were isolated and analysed. Industrial engineering techniques and statistical analyses were used to estimate the effect of crew size, haul-in distance, volume per turn, slope, length of yarding road, and number of logs/acre, on production and costs, results being shown in graphs. Formulae and tables for estimating production rates for various combinations of factors and examples of their use for similar equipment and conditions are given. The effects of different variables on the phases of the operation are discussed. [For. Abs. V. 16, No. 4]

Properties

Report of the Third Conference on Wood Technology, May 1954. *FAO For. Developm. Pap.* No. 7, 1955.

The report of the proceedings is given in English, French and Spanish. The bulk of it (pp. 72–204) consists of a series of Annexes, in English only: (1) Recommended methods of test for evaluating the properties of solid timber; (2) Recommended methods for test for evaluating the properties of veneer, plywood, and other glued veneer constructions; (3) Progress report on development of test methods for evaluating additional properties of fibreboards; (4) Resistance of wallboards to pull-through of nail-heads; (5) Fibreboard puncture test; (6) Brief descriptions of some fire-test methods used for wood and wood-base materials. [For Abs. V. 16, No. 4]

Sekhar, A. C., and Sharma, R. S. New formula for variation of compressive strength with grain angle in timber. *Curr. Sci.* 24 (1), 1955 (3–4).

The following formula is presented:

$$\sigma\|/\sigma\theta = 1 + P\sin^2\theta$$

where P is a parameter depending on the species and the stresses, and other symbols are those in Kollmann's formula. The new formula is claimed to be simpler than either Kollmann's or the Hankinson formula. Some data based both on experimental work and on the use of the three different formulae are presented and compared. [For. Abs. V. 16, No. 4]

Grossman, P. U. A., and Kingston, R. S. T. Project T.P.16. The rheology of wood Subproject T.P.16–4. The mechanism of creep. Progress report No. 1. Superposition tests. Division of Forest Products, C.S.I.R.O., Melbourne. 1955.

Special wood specimens have been loaded and unloaded after daily intervals, and creep curves calculated under the assumption of the principle of superposition. The results of tests are graphed and tabulated. [For. Abs. V. 16, No. 4]

Chipping

Brown Co. explores wastewood chippers and bark removal methods. *Paper Tr. J.* 139 (19), 1955 (110–2).

Describes the operation of Carthage Slab (disc-type) and Equi-Flow (drum-type) chippers, and of a new system of removing the bark from the chips by a combination of abrasion and air aspiration. The machines are used in the chipping of sawmill waste for pulping. [For. Abs. V. 16, No. 4]

Chipcore

Kollmann, F. European methods of manufacturing chipboards. *Holz-Zbl.* 81 (52), 1955 (642–3).

Brief descriptions of procedures used (the name of the company or the product is given): JI-TE Fabrikker, Åstorp, Sweden; Novopan; Curvi-Board; Interwood; Behr boards; Wirus boards; Okal boards Norddeutsche Homogenholz–Werke; Rowi boards; Tavapan; Bremmer boards; Bartrev boards; Weyroc boards; Plimberite boards, and Qvenild boards. [For. Abs. V. 16, No. 4]

Waste Utilization

Hansen, Harold, and Copian, L. P. The simultaneous burning of bark and coal. *Tappi* 38, no. 10: 634–40 (Oct., 1955).

Faced with the requirement for additional steam capacity, the Champion Paper & Fibre Co. of Canton, N.C. decided that a new steam-generating unit firing bark and coal was needed. Studies of existing methods for efficient utilization of bark were made and based on these studies and the company's extensive experience with bark burning, it was decided to install a spreader stoker-fired boiler of the two-drum, single-pass, baffeless design. The unit has a water-cooled furnace, superheater, heat-recovery equipment, and dust collector. Nominal rating is 200,000 pounds of steam/hour at 425 p.s.i. and 750° F. The installation is designed to burn unhogged bark and coal in combination or alone. The bark is distributed in the furnace by pneumatic distributors, and coal is distributed by mechanical feeders. The spreader-stoker traveling grate is of the rear-ash discharge type. There is no bark storage, since the unhogged bark is fired directly as received from the drum barkers. Coal is used to supplement the bark and also to even out the steam flow. The control system is arranged so that the unit fires all the bark it receives and at the same time maintains any set minimum loading by burning coal at the required rate. The plant steam pressure is maintained by one of the other boilers in the plant. The excellent performance of the unit is evidenced by the data collected over a typical five-day 24-hour period. Bark evaporation rates (pounds of steam/pound of bark) are in the order of 3.5. Grate-refuse combustible runs in the order of 1.5%. [Bul. Pap. Chem. V. 26, No. 3]

Todd, A. S., Jr. Pulpwood from small sawmill and logging residues: problems and opportunities. *J. Forestry* 53, No. 6: 416–19 (June, 1955).

The author discusses the reasons for the comparatively insignificant salvage of logging waste from pulpwood in the South, the most important of which is the small size of the average sawmill as compared with operations on the west coast. Based on a survey in a typical South Carolina lumbering area, salvage problems, methods, and possible solutions are reviewed. [Bul. Pap. Chem. V. 26, No. 3]

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Session III—Preservation of Wood Materials Used in Building

THE OSCILLATING PRESSURE METHOD OF WOOD IMPREGNATION. M. S. Hudson, Consulting Chemist, Spartanburg, S. C.; and Sten Henriksson, Boliden Mining Co., Skelleftehamn, Sweden.

A method for preservative impregnation of woods that are resistant to treatment by the usual pressure processes is described. The process developed in Sweden by Henriksson utilizes rapid cycling of vacuum and pressure to obtain penetration of preservative salts in aqueous solution into unseasoned wood. The process begins by submerging the evacuated wood in the preservative solution in a treating cylinder. The pressure is then raised rapidly to about 120 psi followed by a pressure reduction to about 24 inches vacuum. Oscillation of the pressure between these limits is carried out about twice a minute at the beginning. The period between cycles is gradually lengthened until at the end of 8 hours treating, the period is 4 to 6 minutes.

Difficult-to-treat species like spruce and fir have been successfully treated by the process in a commercial plant in Sweden with good results as to penetration and retention of preservative. Tests of the process in the U. S. on several western conifers and eastern hardwoods will be carried out this year.

The paper discusses the underlying physical principles involved in the treatment of wood by this process.

Session IV—Marketing—A Management Tool from Production through Retailer

NEW PERSPECTIVES FOR A GROWING GIANT. P. H. W. Creden, Edward Hines Lumber Co., Chicago, Ill.

A motivation study of the homeowner market for lumber and other building materials, made by Pierre Martineau, research director of the Chicago Tribune, will be interpreted.

The study revealed that many lumber dealers are overlooking tremendous sales possibilities by failing, in their merchandising, to identify raw lumber with its finished products. These products are highly effective motivating factors for consumers, according to Martineau.

The study charted the attitudes of some 1,200 home owners about the do-it-yourself idea and about lumber yards. Also surveyed were 15 lumber yards and their customers. The do-it-yourself trend has an appeal for all classes of workers, it was found, and wives play an important role in the deciding phase (what to do, what to buy, etc.), as well as joining in the actual work.

Lumber merchandising geared to these findings will pay less attention to technical data, price, and dimensions. Instead it will point up how finished products—cabinets, lawn furniture, house wings, etc.,—fit into the consumer's vision of ideal home life.

Session V—Keeping Abreast in Wood Gluing

GLUING HIGH PRESSURE DECORATIVE LAMINATES. Joseph Coufal, National Adhesives, New York.

The growth, present production, uses, and future of high pressure laminates will be discussed. Methods of using the following will be described: casein, urea, contact cement, soyas, melamines, phenols, resorcinols, vinyl phenols, and polyvinyls.

The Kwik-Klamp process will be illustrated, including air hose press, electronic press, grooving glue spreader, core materials. Self-edge banding will be covered, as well as contact cements, using urea with strip heaters, urea with electronic presses and wood welders.

Session VII—Improved Techniques for Wood Drying

ESTIMATING THE MOISTURE CONTENT OF LUMBER DURING THE DRYING PROCESS. W. E. Pratt, California Redwood Association, San Francisco, Calif.

The information obtainable by weighing units of stuck lumber at various times during the drying process is evaluated and compared with the information obtainable by conventional sampling techniques.

COMPARISON OF THREE METHODS OF DETERMINING WHETHER SOUTHERN PINE POLES ARE WELL AIR SEASONED. J. S. Mathewson, U. S. Forest Products Laboratory, Madison, Wis.

A resistance type of electric moisture meter and increment borings were used to determine the transverse moisture distribution in well air-seasoned class 5, 40-foot southern pine poles. An ohmmeter called a megger was used to determine the electrical resistance of the poles when measured between two twentypenny nails driven 25 feet apart in each pole. At a depth of 0.3 of the radius, at which point the moisture content is theoretically the transverse average moisture content, the moisture-meter readings corresponded very well with the average moisture content obtained by distillation of the borings. When the moisture-meter readings were between 20 and 30 per cent, the corresponding electrical resistance values obtained with the megger were in most cases between 2.5 and 3.5 megohms, which experience has shown are desirable as a criterion of readiness of the poles for treatment with creosote.

Session VIII—Chemicals from Lignin, Hemicellulose, and Other By-Products

WHOLE TREE HARVESTING. R. C. Sproull, Philip Morris Co., Richmond, Va.; and W. L. Belvin and R. B. Parker, Herty Foundation, Savannah, Ga.

The general economics of whole tree harvesting and collection will be discussed. Differences in fiber dimensions and wood structure of different sections of the tree will be presented and related to properties of paper made from different sections of the tree. This will be discussed with respect to sawmill chip utilization. Potential uses of portions of the tree will be reviewed.

ALKALI AND THIO LIGNINS FROM PINE BARK. J. B. Doughty, F. W. Taylor, and W. T. Henery, West Virginia Pulp and Paper Co., Charleston, S. C.

Lignin was recovered by acidification of the spent liquor from various cooks of pine bark in aqueous sodium hydroxide and kraft cooking liquor, respectively. Process data were collected and some properties of the lignin products determined. Product yields

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varied with the alkali-bark ratio but maximum recovery was of the magnitude predicted by the 72% sulfuric acid analysis method. The methoxyl and sulfur content and acetone solubility of the lignin also varied with the changes of the chemical compositions of the cooks.

Session IX—Machining Composition Board and Other Wood Products

SANDING PARTICLE BOARD TO THICKNESS. David A. Haile, Rock Island Millwork Co., Rock Island, Ill.

The over-all need for close tolerances in machining particle board, as dictated by its end use, will be discussed. The paper will describe equipment presently in use to obtain this required tolerance and a method to evaluate and maintain this tolerance. A particular product will be cited as an example and a detailed study evolved, including process charts and graphs. Actual production records will be presented as evidence of these studies put in actual practice.

EFFECTS OF BORING SPEED AND FEED RATE ON THE STRENGTH OF GLUED DOWEL JOINTS IN TENSION. Robert J. Hoyle, Jr., State University of New York College of Forestry, Syracuse.

Bored holes in wood should have smooth wall surfaces free of flowed lignin or charred areas, if they are to be used for glued dowel joints. Wall smoothness and freedom from charring are desirable qualities in bored holes for purposes other than dowel joints. Experiments were conducted to determine the effects of these two quality features on the strength of dowel joints. The controlled variables were boring tool speed, feed rate, species of wood, and dowel type.

On dense species of uniform structure, such as hard maple, wall surface smoothness was not greatly reduced as feed rate was increased. In the case of low density species such as northern white pine, wall quality and joint strength were materially reduced as feed speed was increased.

The effect of tool rpm upon joint strength was quite pronounced. High tool rpm yielded joints of lowered strength. In certain cases very low tool rpm had a similar effect. These results were attributed to heating of the tool and the wood. The intermediate speed used in the tests, 2880 rpm, appeared to be most suitable. The interactions of wall surface smoothness and overheating of the tool and wood are discussed at some length in the report.

There was no significant difference between the strength of joints made with plain dowels and with spiral grooved dowels.

The results are presented to illustrate the effects of factors involved in the boring process, rather than as specific recommendations. Continued research is in progress to develop additional information on the wood boring process.

AN ANALYSIS OF THE LUMBER PLANING PROCESS: PART II. Peter Koch, Michigan State University, East Lansing, Mich.

This study is Part II of an investigation pertaining to the peripheral-milling process of planing lumber. The experimentation determines some relationships between cutter-head horsepower and various combinations of specimen, cutter-head, and feed factors. The power demand curves are interpreted through comparison with simultaneously taken one-micro-second photographs of the forming chips. Secondary consideration is given to the quality of surface obtained. The cutterhead variables as well as the feeds and speeds employed are in the range of those commonly used in industry, i.e., feed speeds to 500 FPM with cutterheads ranging up to 9-inch cutting-circle diameter and carrying up to 8 knives.

Session X—More Complete Utilization in Logging and Milling

REDUCING SAWMILL WASTE 90 PER CENT IN SIX YEARS. E. P. Ivory, Ivory Pine Co., Dinuba, Calif.

This paper will point out various merchantable products made from formerly wasted materials at the plant of Ivory Pine Co., Dinuba, California. It will show how one fraction after another has been prepared and placed on the market, among them shavings, sawdust, wood flour, raw pulverized bark, composted bark dust, car strips, and wood chips. It will point out the influence of geographic location of the mill on the manner in which various segments of waste can best be utilized. It will show how manufacturing methods, such as the lack of a boiler, or the practice of debarking logs, has first created the need for waste disposal and then pointed the manner in which it might be accomplished.

The paper will also show the influence of species cut on the end uses of the waste. It will describe the types of customers who use each different product and show how business romance can touch the most prosaic wood materials. The paper will develop the way in which sawmill waste has been reduced from approximately 300 tons per day, all of which had to be consumed in a burner, to approximately 30 tons per day and point the possibility of almost 100% utilization within the next five years.

Session XI—Composition Boards—What the User Wants

THE USE OF COMPOSITION BOARDS AND OTHER WOOD-BASE MATERIALS IN MASS HOME BUILDING. W. J. Worth, National Homes Corp., Lafayette, Ind.

The paper will cover general physical properties desirable, specific properties important to prefabrication, and the use of wood products as finish material. Wood

E. P. IVORY

W. J. WORTH

R. H. YALE

I. J. BARBER

products in such structural applications as housing, schools, and commercial buildings will be discussed.

The influence of building codes and insurance rates will be pointed out, and the outlook given for future uses of wood in mass building.

COMPOSITION BOARD HAS FOUND ITS PLACE IN THE FURNITURE INDUSTRY. R. H. Yale, Poinsett Lumber and Manufacturing Co., Pickens, S. C.

Wood aggregate materials have found a definite place in the woodworking industry. Acceptance by the consumer is dependent upon how much is expected of the product and what claims are made for it. Like solid lumber, composition board does have limitations, and consideration should be given to the ultimate use to which the product will be subjected when selecting the material to be used.

Wood composition board should not be considered a substitute for wood but as a by-product—thereby being equally as effective as solid lumber. There are many types of composition boards on the market today, just as there are many species of lumber available. It depends upon the ultimate use just what type should be selected.

The user wants a product that will give satisfactory service, at a more economical figure than solid lumber, and it is through continued research and development by the woodworking industries that these demands can be fulfilled.

Several charts will be shown to give the results obtained in evaluating various types of wood aggregate boards, and conclusions will be drawn to show what constitutes a good product.

Session XII—How to Select a Better Finish for Furniture

NEW APPROACHES IN WOOD FINISHING. Albert J. Kirsch, American Cyanamid Co., New York, N. Y.

This paper lists the possible properties desirable in a wood finish. Besides possessing the inherent decorative and protective features, the finish must be adaptable to modern mass production scheduling. At present, the lacquer and the low bake furniture finish are most popular.

Board surfacing resin and air-curing polyester vehicle represent the newer means for finishing wood. While maintaining the decorative quality, they provide still better resistance and wearing properties, and faster finishing and packing schedules. While the board surfacing resin is limited to finishing of flat surfaces like table tops, door and wall paneling, the entire operation is performed in a press with no subsequent rubbing or polishing required.

The polyester vehicle also provides a one-coat application. Like conventional finishes, it may be applied by spray. For best film and "pot life" properties, the use of a dual spray system is required.

P. H. KRUPP

J. A. HOFFMAN

INFRA-RED DRYING OF WOOD AND FURNITURE FINISHES. I. J. Barber and P. H. Krupp, Fostoria Pressed Steel Co., Fostoria, Ohio.

Advantages of using infra-red drying are its positive control, flexibility, efficiency, and better fuel utilization to minimize costs. Electric energy can be controlled better than any other fuel, ovens can be zoned longitudinally as well as throughout the cross-section to provide temperature variations as required, electric controls can automatically purge the oven of fumes before and after operation, and electric controls can shut off energy immediately in case of conveyor stop and there will be no lag in the source. Heating ceases promptly or can be reduced to hold temperature already built up in the product.

Infra-red ovens can be recontoured with a small amount of work and standard parts. They can be relamped with different size lamps to give entirely new heating range when required. By using electric controls, the intensity of infra-red ovens can be changed instantly.

With infra-red, there is no lost energy through heating air where losses are great. It is not necessary to heat oven walls before heating the product, and no preheating period is required. Better utilization of fuel cuts operating cost. This system can eliminate boiler facilities.

Case histories and test date will be given for infra-red drying of stains, fillers, lacquers, synthetics, and combination coats on flat panels, and stains, fillers, and lacquers on assembled furniture.

Session XIII—Packaging and Shipment of Furniture

CUSHIONING MATERIALS FOR THE PROTECTION OF FURNITURE. John A. Hoffman, Kimberly–Clark Corp., Neenah, Wis.

The modern trend in packaging furniture for transit is rapidly moving away from heavy and expensive open wooden crates, built by hand to fit the product. Leading furniture manufacturers have demonstrated that their products can be packaged more economically and given greater protection by wrapping it in a protective blanket and placing it in a close-fitting, double faced, corrugated fibreboard box which has a wooden skid attached to its bottom.

The interior blanket provides cushioning and surface protection for the furniture. Interior packaging materials in common use include wood fiber felt, creped cellulose wadding, cotton wadding, indented paper blankets, and pads made of excelsior or aerated newspaper enclosed in Kraft wrappers. Desirable quality attributes in these materials include those of non-abrasiveness, non-staining or corroding, conformability, non-linting or dusting, and cleanliness.

The most important requirements of the protective interior blanket are that it have load-distribution and shock absorption abilities. The attribute of load-distribution is particularly important since it determines the ability of the material to prevent abrasion or pressure marking of the furniture surface. It will be demonstrated that both load-distribution and shock absorption abilities of an interior packaging material are a function of its thickness rather than its weight.

PACKAGING AND SHIPMENT OF FURNITURE BY RAIL. J. C. Anderson, Southern Weighing and Inspection Bureau, Atlanta, Ga.

Furniture when shipped via rail must conform to the furniture packing regulations published in Uniform Freight Classification, Consolidated Freight Classification, or governing tariffs. There is no provision for rates on furniture not packed in accordance with the packing requirements. Both the carrier and shipper are bound by law to comply with these regulations.

The specifications are likened to a blueprint or outline of methods approved for shipping furniture by rail. In brief, they specify the minimum grade and quality of packing material, the nature and kind of inner packing (whether padding, clearance, or other means). Alternative methods are authorized for packing each article, but each package is separate and distinct.

Subsequent to the adoption of regulations which became effective in 1948, many changes have been made to meet the needs of the industry. Shippers have a wide variety of methods approved for packing each article of furniture, which are clearly outlined in the specifications, so that shippers and railroads alike will know if articles are properly packed in accordance with tariff requirements.

Session XIV—Improved Plywood Products through Technology

THE CARE AND MAINTENANCE OF VENEER KNIVES. N. Bowditch, Simonds Saw and Steel Co., Fitchburg, Mass.

This paper focuses on the part that the veneer knife plays in the lathe operation. The major steps of knife manufacture are briefly covered. The meaning of a straight keen cutting edge is brought out. Without such an edge the lathe operator must take much valuable time to get his knife into position, which puts it under great stress. Wear on the cutting edge and honing in the lathe have a very close bearing on making a quality product. The positioning of the knife in terms of its pitch, and relative to chuck centers is considered as to its effect on lathe performance.

Many plant supervisors have underestimated the importance of a good grinderman and the value in a modern or well maintained grinding machine. More damage to a knife can be traced to grinding than may be found at the lathe. Good grinding practice and points to remember will be discussed. Certain dangers to knife and lathe, the result of peculiarities in wood, are also covered.

ENGINEERING DESIGN OF A VENEER AND PLYWOOD PLANT. E. H. Merritt, Ericsson Merritt, Inc., Lockport, N. Y.

A broad discussion from an engineering viewpoint of the many factors which are involved in and affect the design of a modern veneer and plywood plant. Several of the factors are basically economic but their effect on the engineering design is often controlling.

J. C. ANDERSON

N. BOWDITCH

Plant location, climatic conditions, transportation, character and availability of timber supply, labor, type of product, markets, and extent of integration of the project are some of the factors discussed in the light of their effect on design.

The overall result constitutes a summary of the detailed engineering data which is required in the execution of a rational design of a specific plant.

MAINTENANCE OF QUALITY IN THE MANUFACTURE OF MOLDED PLYWOOD. R. A. McKay, Brunswick–Balke–Collender Co., Marion, Va.

This paper will cover in general the entire process for the manufacture of molded school classroom chair seat and back panels. This will include strict purchase specifications, receiving inspection, storage and conditioning, flattening face stock by R. F. heat, presanding the faces, molding, shaping, boring and countersinking of rivet holes, edge sanding, face polishing, inspection, and finishing.

Face veneer flattening, presanding, and molding will be covered in detail. Our purchase specifications for face veneer are very strict and include items probably not found anywhere else in the furniture industry. White maple and sap birch is specified by common and scientific names. Thicknesses and surface dimensions are limited to allowable tolerance. The veneer must be flat, tight cut, smooth, and the tight side must be marked so that it is the exposed surface of the panel. The suppliers package must be approved, in an attempt to reduce damage in shipment and storage. Moisture content must be between 6 and 10 per cent. All these requirements are necessary not only in reducing rejects due to splitting and cross breaks, but also to improve the serviceability of the panels by minimizing face checking. The end result is well-designed, attractive, and durable chair panels.

To further improve the product, rough sanding of the panel faces after molding is eliminated, to prevent excessive sanding due to the compound surfaces. This is done by precision sanding face veneer prior to molding. The panels are then lightly polished on a belt sander as the final machining operation.

A problem encountered in presanding was wavy veneer, in which high areas were oversanded. This was eliminated by flattening the wavy stock in a five-opening R.F. press.

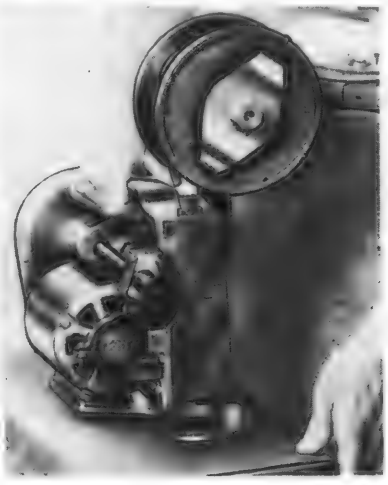
The machine line will also be described. This includes automatic shapers, boring and countersinking, edge sanding, and face polishing. All panels are inspected 100 per cent before being sent to the finishing room where they receive a conveyor finish.

FPRS News-Digest, Continued

NEW PRODUCTS—LITERATURE

Portable Wire Stitcher

A light-weight portable wire stitcher, model OG, is being manufactured by Ordnance Gauge Co., Philadelphia 25, Pa. The unit weighs 15 pounds, is easily carried to any plant location, and can be used for every conventional task done on pedestal stitchers.



The OG makes about 200 stitches per minute on single or double fluted board, as well as on fiber or wood. Optional equipment includes special arms for odd-shaped cartons and an open head for closing cartons.

Sawmill Equipment Catalog

A comprehensive catalog of data on the sawmill industry has been issued by R. Hoe & Co., 910 E. 138 St., Bronx, N. Y. A large, detailed section deals with general information on sawmill operation as well as a history of the saw and the Hoe organization.

Other sections cover chisel tooth saws, bits and shanks, solid tooth circular saws, band and gang saws, carbide-tipped saws, machine knives, and grinding wheels. Also included is a step-by-step review for setting up a sawmill and suggestions for maintenance of the mill.

High-Speed Vibrating Screen

A high-speed vibrating screen of possible interest to producers of chipcore, plastics, etc., has been developed that is 30 to 80% faster than previous mechanical screens. The new screen has a speed of 3,300 rpm when set for 1/32-inch stroke, according to Hewitt-Robins, Inc., Stamford, Conn.

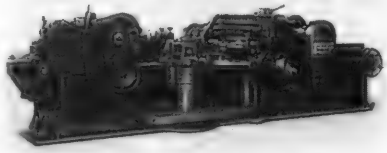
Automatic Arc Suppressor

An automatic arc suppressor (AS3W), designed specifically to make electronic wood gluing a safer operation, has been developed by the Thermatron Div., Radio Receptor, Inc., 251 W. 19 St., New York. The suppressor can be added to any electronic generator.

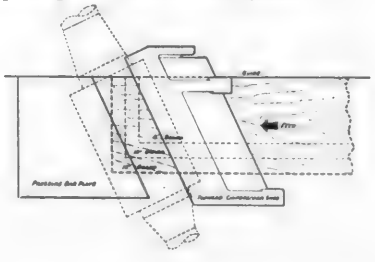
The device works by watching for a change in electrical resistance. When such a change is detected, it indicates the presence of an arc. Almost immediately, thyraton electronic switches fire, stopping the generator in one-millionth of a second. The device is so sensitive that if an operator accidentally touches the hot electrode, it will automatically shut down the equipment before he is hurt.

New Planer and Matcher

For many years the S. A. Woods Machine Co., 27 Damrell St., Boston, has been developing a planer and matcher employing radical departure from the customary methods of planing and sizing lumber. Their objectives included: full motorization; minimum vibration and wear; improved control of stock being milled; prevention of end sniping; and flexibility to set direction of cut at proper angle to give greatest consideration to faulty characteristics of lumber itself.



The new Woods A-480M Diagonal Planer and Matcher is the result. Continuous operation over several months milling various lumber has shown beneficial results: elimination of sniped ends; smoother finish on knots and cross grain; less power consumption in feeding stock; and reduction in friction and wear on feed rollers. The diagonal cutterhead also serves to hold stock against the guide fence, requiring less lead in the guide.



The new machine is said to be able to improve finish and thereby upgrade lower grade stock. It weighs in at 34,000 lbs. equipped with JM5 Profiler, handles stock up to 600 lineal feet per minute.

Chip Dehydrator

Green wood chips are reported dried uniformly to about 8 per cent moisture content in Ardrier Dehydrators. The dehydrators are built for Arnold Dryer Co. by Heil Co., Milwaukee, Wis.

The three-stage drying system consists of three drums built into a single unit which rotates at a regulated speed. Compound flights on both surfaces of inner and intermediate drums continuously pick up material from the bottom and drop it into the hot air stream. Light material is sucked through the drums immediately, heavier materials move more slowly for uniform drying.

Contact Adhesive

The addition of a contact bond cement to its line of woodworking glues has been announced by National Casein Co., Chicago, Ill. The new glue adhesive can be used for bonding plastic laminates to plywood, wood veneer, and other materials, as well as other material combinations.

The contact bond gives a glue line which is highly water resistant and which withstands oxidation, oils, grease, and most chemicals. It is fast drying, with a strong bond obtained within 15 or 20 minutes under normal temperature and humidity conditions.

New Tractor Line

A new industrial division has been established by Massey-Harris-Ferguson, Inc., Racine, Wis., to market a full line of light and medium-duty industrial wheel tractors and allied equipment. Franchises are now being issued throughout the country, with production having started in late March.

Supplementing the tractor line is a full complement of allied equipment for lumbering, construction, materials handling, etc. Attachments include loaders, back hoes, lift forks, dozer blades and trenchers.

FPRS News-Digest, Continued

Carloading Check Chart

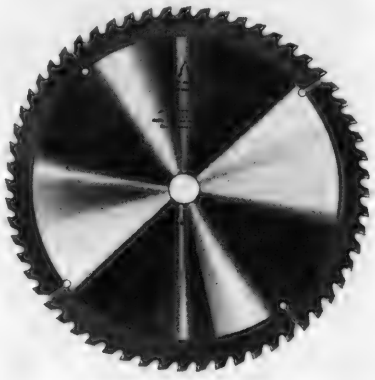
An illustrated chart on carloading procedures for anchored loads, designed for shipping room and loading dock personnel, is offered by Signode Steel Strapping Co., 2600 N. Western Ave., Chicago. It includes instructions for preparing the car, wrapping anchor plates, draping the car, bulkhead construction, and use of strapping tools.

High-Frequency Equipment Bulletin

"Now—Automation in the Glue Room" is the title of Bulletin HF-256 released by Union Tool Corp., Warsaw, Indiana. Covering their line of standard high-frequency woodworking machinery, the bulletin describes and illustrates the roto-gluer, electro-gluer, finger-joint bonding line, and assembly clamp.

Carbide-Tipped Saw Blade

Addition of the new style D45R carbisaw blade to their present all purpose saw and smooth trimmer is announced by North American Products Corp., Box 210, Edwardsville, Ill. A double 45° corner bevel on alternate teeth, followed by a straight raker



tooth on a second diameter, reportedly doubles the chip load per tooth. The strong bevel tooth takes the heavy duty cutting load while the raker tooth clears the cut.

The stronger tooth angles are claimed to give greater wear resistance and are suited to all types of cuts in plastics and woods not requiring the shear cutting action of the alternating top bevel tooth form.

Coating for Concrete Forms

A protective coating has been developed which prevents concrete, mud, and water from adhering to wood or plywood concrete forms. It is being manufactured under the name "Form Kote" by Form Kote Inc., 700 W. Virginia St., Milwaukee, Wis.

The product reportedly penetrates the wood and produces a protective coating unaffected by mars, scratches, or other abrading. It is applied with roller, brush, or spray and the forms may be used immediately after application.

Log Load Binder Release

A quick-acting safety release for log load binders developed by C. A. Wilson, logging superintendent, and Gordon Boyes, master mechanic, J. Neils Lumber Co., is now being produced and sold by Electric Steel

Foundry Co., Portland, Ore. The device permits load binders to be released from a safe distance from the load by pulling the safety catch with attached line. It is designed to eliminate the danger of falling logs when binders are released.

Lumber Trailer

A four-wheel trailer type unit for transporting lumber and other materials around yards and industrial plants is being produced by Hawkeye Industries, Longmont, Colo. Known as Wheel-It, the trailer is of welded steel construction and has a load capacity of 6000 lbs., yet weighs only 700 lbs.

Two tapered roller bearings for pivoting allow the unit to be turned completely around in slightly more than its own length. A telescoping tongue accomodates loads up to 24 feet long and will fit a standard one-bar trailer hitch.

End-Check Preventative

Sealtite end-coating, a chemical for prevention of end-checks in logs and lumber, is described in a bulletin published by Chapman Chemical Co., Memphis, Tenn. The chemical is said to reduce end-checking by sealing the end grain of the wood, allowing moisture to escape uniformly during seasoning and thus minimizing internal stresses.

The low-cost chemical may be applied by spray, brush, or swab and is available in 52-gallon drums in a clear liquid or red and green colors.

NEW PUBLICATIONS

Changing Volume and Taper of Pole-Size Shortleaf Pine in Southern Illinois. W. R. Boggess and F. W. McMillan. Forestry Note 66. U. of Illinois Agricultural Experiment Station, Urbana, Ill.

Yellow-Poplar Responds to Preplanting Ground Treatment. R. W. Merz and R. F. Finn. Tech. Paper 150, Central States Forest Experiment Station, Columbus, Ohio.

Debarking Machines and Methods. Equipment Handbook Release 235. American Pulpwood Assoc., 220 East 42nd St., New York 17. Evaluates the five basic types of debarkers—drums, rossers, flail, hydraulic erosion, and cambium shearing.

Pulp Chips from Sawmill Leftovers. Equipment Handbook Release 244. American Pulpwood Assoc., 220 E. 42nd St., New York 17.

Fine Hardwoods Selectorama. Fine Hardwoods Assoc., 666 Lake Shore Drive, Chicago. A reference guide describing and illustrating over 400 hardwood species. $1.50.

Teco Products and Services for the Users of Wood and Forest Products. Timber Engineering Co., 1319 18th St., N.W. Washington, D. C. Describes use of six different types of timber connectors in wood construction.

A Combination Skidder-Loader. Equipment Handbook Release 248. American Pulpwood Assoc., 220 E. 42nd St., New York 17. Discusses mounting a crane and winch on a 1-½-ton truck chassis, converting it into a useful woods vehicle.

Logging Arch for Direct Attachment to 3-Point Hitch Tractor. Equipment Handbook Release 249. American Pulpwood Assoc., 220 E. 42 St., New York 17.

The Wagner Logmobile. Equipment Handbook Release 251. American Pulpwood Assoc., 220 E. 42 St., New York 17.

The Cambio Barker. Equipment Handbook Releases 252 and 253. American Pulpwood Assoc., 220 E. 42 St., New York 17.

Briquetting Planer Shavings for Pulp (Progress Report). Equipment

FPRS News-Digest, Continued

Handbook Release 254. American Pulpwood Assoc., 220 E. 42 St., New York 17.

Effectiveness of Boat Nails. E. G. Stern. Wood Research Laboratory Report 22. Virginia Polytechnic Institute, Blacksburg, Va.

Drivability and Holding Power of Heavy-Duty Screwtite Masonry Nails in Concrete. E. G. Stern. Wood Research Laboratory Report 23, Virginia Polytechnic Institute, Blacksburg, Va.

Where to Buy. 1956 Directory of West Coast Lumbermen's Assoc., 1410 S. W. Morrison St., Portland 5, Ore.

Annual Report. American Forest Products Industries, Inc., 1816 N St., N. W., Washington 6, D. C.

Safety Bulletin. U. S. Dept. of Labor Bulletin 1190. Govt. Printing Office, Washington 25, D. C. $.45. Analyzes more than 1,000 circular saw accidents occurring in woodworking industries and gives safety tips.

The following publications are available without charge from the U. S. Forest Products Laboratory, Madison, Wis.

Comparison of Methods for Estimating Summerwood Percentage in Wide-Ringed Second-Growth Douglas-Fir. D. M. Smith. Report 2035.

Fluorescence Microscopy for Measuring Fibril Angles in Pine Tracheids. R. O. Marts. Reprint from Stain Technology.

How Wrapping Keeps Wood Parts Stable. J. S. Mathewson, Reprint from Wood and Wood Products.

Interlaminar Shear Strength of Glass-Fiber-Reinforced Plastic Laminates. F. Werren and B. G. Heebink. Report 1848.

Mechanical Properties of Aluminum Honeycomb Cores. E. W. Kuenzi. Report 1849.

Basic Shear Strength Properties of Metal-Bonding Adhesives as Determined by Lap-Joint Stress Formulas of Volkersen and Goland and Reissner. H. W. Eickner. Report 1850.

Elastic Stability of Cylindrical Sandwich Shells Under Axial and Lateral Load. E. E. Haft. Report 1852. Presents a linear solution for determination of loads under which cylindrical sandwich shell will buckle.

Special Methods of Seasoning Wood. Solvent Seasoning. Report R1665-2.

Double Diffusion Treating of Wood. Method described utilizes two chemicals that diffuse separately into wood, then react to form copper chromate. Reprint from Chemical and Engineering News.

Comparison of Wood Preservatives in Mississippi Post Study (1955 Progress Report). J. O. Blew and J. W. Kulp. Report 1757.

News and Views of this Kiln Drying Business. R. C. Rietz. Report 1769-7. Discusses advantages and disadvantages of package-loaded dry kiln.

Wood Molasses for Stock and Poultry Feed. Report 1731 (revised). Describes tests in which wood molasses made from manufacturing residues and other scrap wood was fed to livestock and poultry, and was found generally as palatable and nutritious as blackstrap molasses.

The Liquor-to-Wood Ratio as a Variable in Neutral Sulphite Semichemical Pulping. E. L. Keller and J. N. McGovern. Reprint from TAPPI.

Importance of Wood Quality in Tree Breeding. B. H. Paul. Reprint from Journal of Forestry.

Durability of Low-Density Sandwich Panels of the Aircraft Type as Determined By Laboratory Tests and Exposure to Weather. V. C. Setterholm, B. G. Heebink, and E. W. Kuenzi. Report 1573-C.

Supplement to Bolt-Bearing Properties of Glass-Fabric-Base Plastic Laminates. R. L. Youngs. Report 1824-A

Supplement to Bolt-Bearing Properties of Glass-Fabric-Base Plastic Laminates (Effect of Laminate Thickness). R. L. Youngs, Report 1824-B

Types of Ventilated Lumber Dry Kilns. Report 1900-2

Study of Preservative Treatment of Lumber. J. O. Blew, Jr. Report 2043. Compress various pressure and non-pressure treating processes on the basis of tests of the depth of penetration in the wood and the amount of preservative chemical retained by the wood.

Procedures for Measuring the Mold Resistance of Protein Glues. Report 1344. Presents two simple techniques by which the mold resistance of soybean and casein glues can be evaluated.

Bond and Magazine Book Papers and Milk-Carton Paperboard from Old-Growth Douglas-Fir and Red Alder Pulps. P. K. Baird, J. S. Martin, and D. J. Fahey Report 2042.

Pulping Characteristics of Lake States and Northeastern Woods. E. R. Schafer, J. S. Martin, and E. L. Keller. Report 1675.

Specific Gravity, Shrinkage, and Strength of Tanoak. B. H. Paul. A. W. Dohr, and J. T. Drow Report 2041.

Relationship Between Specific Gravity and Percentage of Summerwood in Wide-Ringed, Second-Growth Douglas-Fir. D. M. Smith. Report 2045.

Drying Schedule for Thin Red Oak. K. E. Kimball. Reprint from Southern Lumberman.

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EMPLOYMENT SERVICE

Positions Offered

No. E 225—Large progressive Texas firm plans training program to develop production management personnel for South's newest and largest all-electric forest products plant. Seeks recent or June 1956 forest utilization graduates interested in fields of power generation, product shipment, machine finishing and primary production. (May)

No. E 226—Research position requiring Ph.D. or equivalent in wood technology or pulp and paper for Group Leader in Research Center. Strong background in chemistry and understanding of polymeric materials desirable. Reply in confidence enclosing complete resume to the Borden Co., Chemical Division, Philadelphia Research Lab. P. O. Box 9524, Philadelphia 24, Pa. (May)

No. E 227—Machinery company desires forester trained in wood utilization to sell line of fiber preparation equipment in Southwest. Should be 35 years of age or older. Also openings in Midwest and Eastern territories. (Apr.)

No. E 228—Furniture component manufacturer utilizing plastics has opening for fabricating department supervisor with opportunity to advance to general plant supervision. Supervisory ability and wood fabricating experience primary requisites. 50 to 100 employees. Located in small city in southern lake section of Wisconsin.

No. E 229—Eastern veneer and plywood manufacturer seeks recent wood technology graduates, perferably with one or two years experience in some phase of woodworking for sales careers. Will consider current graduates for training program. (May)

Employment Wanted

No. 323—Immediately available. Man with B.S. Forestry. Experience in yard supervision, pre-cutting (housing), limited marketing, milling, grading, selective logging, cruising, small plant layout and production shortcuts, supervising, and training technical, clerical and labor. Age 54. (May)

No. 339—Experienced lumberman, age 37, seeks supervisory position. Thorough knowledge of production costs, utilization, and sales in soft wood and hardwood mills. B.S. Forest Products. (Apr)

No. 345—Young man, B.S. in agriculture, will receive Master of Forestry in forest products from Duke University in June 1956. Seeks immediate position in production or sales in Northeast. Age 27, married. (Apr)

No. 349—Graduate of New York State College of Forestry and National Hardwood Inspection School, age 28, seeks position as yard manager and purchasing agent for hardwoods in East or South. Has six years experience as inspector, kiln operator. (Apr)

No. 350—Experienced lumber superintendent and kiln operator, age 40, graduate of Oregon State College of Forestry, seeks West Coast buying and sales position in wholesale lumber field. Has been in charge of drying, surfacing, and shipment of hardwood and softwoods, some sales. Holds commission in U.S.N.R. (Apr)

No. 351 — Lumber manufacturing executive extensively trained in chemistry, wood technology, and wood utilization with advanced degree from Yale seeks research or manufacturing position. (Apr)

No. 352—Young executive, commerce degree and 20 years' experience in furniture production, design, labor relations, purchasing and sales as general manager, seeks position in South or Southwest, will consider other areas. (Apr)

No. 354—B.S. Forestry, June 1956, U. of Michigan. Age 21. Several summers with U. S. Forest Service and lumber company, seeks job in forestry. (May)

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W-240-B and W-240-D Onsrud 2-Speed Routers
No. 666 Porter Router
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Wysong & Miles Automatic Stroke Sander, mechanical operation
No. 183 Oliver Reversible Belt Sander
43″ and 49″ No. 431 Yates Endless Bed Sanders
No. 430—43″ Solem Ball Bearing Direct Motor Drive Endless Bed Sander
46″ Mershon Ball Bearing Band Resaw
36″ Tannewitz Type G Ball Bearing Band Saw
No. 724 Diehl Straight Line Automatic Cut-Off Saw
G-44 Yates–American Twin Unit Cut-Off Saw
DeWalt Model GE 5 HP Cut-Off Saw
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No. 139 Whitney Ball Bearing Motor Driven Double Spindle Shaper
No. 124 Onsrud Automatic Shaper
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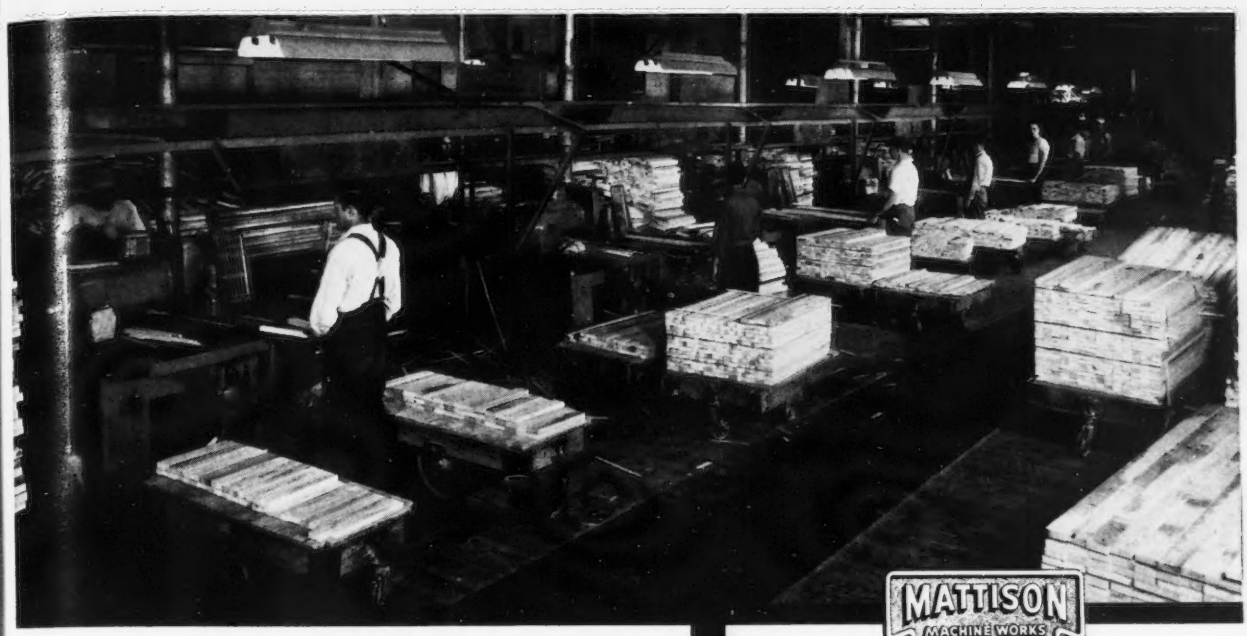


MATTISON
MACHINE WORKS
ROCKFORD, ILL. U.S.A.

$12,000 YEARLY SAVING

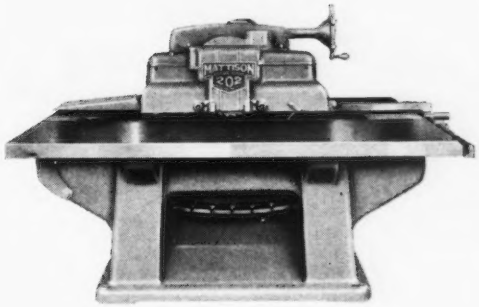
ripping on the Mattison 202

Morgan Manufacturing Co., Black Mountain, N. C., has discovered many advantages in using Mattison Model 202 Straight-Line Rip Saws. It is possible to save $12,000 annually in ripping operations on hardwood stock. Also, these machines do straight-line ripping after which the stock is glued without going through a glue-jointer.

Morgan is one of the largest finished dimension producers in the country, operating a million dollar plant in which every phase of production makes use of the most efficient, modern equipment available.

Close analysis of production efficiency will lead to the selection of Mattison Rippers every time. The Model 202 is a precision machine capable of serving as a jointer as well as a ripper. Two jobs can be done with one machine, saving equipment and labor costs.

Ask your Mattison representative to explain the advantages of overcut construction. And remember—every Mattison woodworking machine is built to the same standard—*for finest quality work at lowest possible cost.*



8 ways to save

- Glue exposed joints directly without going through the glue-jointer. Save ⅛ in. stock on each edge.
- Single chain with one-piece jam-proof blocks under the saw allows cutting sliver edgings.
- Elimination of glue-jointer frees two men for other work. Cost per finished piece drops.
- Ample power and rigid construction mean maximum production.
- Absolute alignment of working parts is assured by hardened, wear-resisting tracks mounted on the base.
- Patented saw jointing device makes every tooth do its share of the work for smooth cuts and less frequent sharpening.
- Every practical safety device is used on the machine.
- Many Mattison machines pay for themselves in the first year or less.

MATTISON
WOODWORKING MACHINERY

Mattison Woodworking Division
545 Blackhawk Park Avenue
Rockford, Illinois

Gentlemen: Please send bulletin on the Model 202 Rip Saw.

Name _____

Company _____

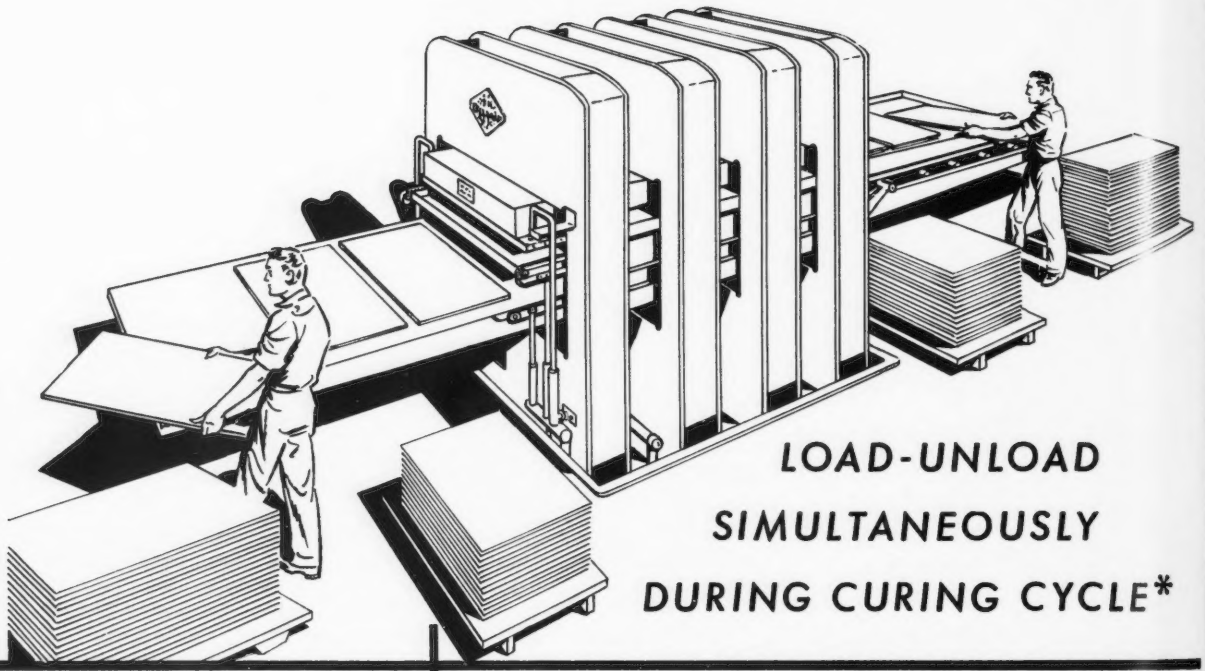
Address _____

City _____ State _____

STOP *idle presstime*... DOUBLE *production with*

FJELLMAN AMERICAN

Autoloading SHUTTLE FEEDER



LOAD-UNLOAD
SIMULTANEOUSLY
*DURING CURING CYCLE**

***HERE'S THE OPERATION STORY OF FJELLMAN AMERICAN'S AUTOLOADING SHUTTLE FEEDER**

The shuttle feeder is simply a means of using the closed or curing cycle of an hydraulic hot press to ready the next load while automatically discharging the finished piece.

Loading is done at both ends simultaneously from cauls stacked with raw materials. When press opens, fresh loads are fed into position from opposite ends, as press ejects the finished piece. Loading and reloading takes place while another load is in cure.

In this manner, work continues unhampered at twice the rate formerly possible.

THE NEW FJELLMAN AMERICAN AUTOLOADING SHUTTLE FEEDER HOT PRESS

The new Fjellman American Autoloading Shuttle Feeder hot press makes short work of the loading cycle, actually doubling the output. Raw materials and finished pieces are shuttled simultaneously to opposite ends without interruption — with minimum crews, reduced idle press time and handling costs.

Such efficiency is coupled with durability. Each Fjellman American shuttle feeder hot press is precision engineered from fine Swedish virgin steel.

This production giant is now available for immediate delivery. Contact a Fjellman American representative today.

FJELLMAN AMERICAN

FJELLMAN AMERICAN, INC.
105 Republic Avenue Joliet, Illinois